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ABSTRACT

This booklet contains a detailed review of the aeronautical research conducted at Langley Research Center during the 50 years after its construction in 1917 as the first research laboratory for the National Advisory Committee for Aeronautics. The research is discussed in five parts, by decades: 1917-27, 1928-37, 1938-47, 1948-57, 1958-67. Photographs of aircraft are presented throughout the review. (PR)

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FIFTY YEARS OF AERONAUTICAL RESEARCH

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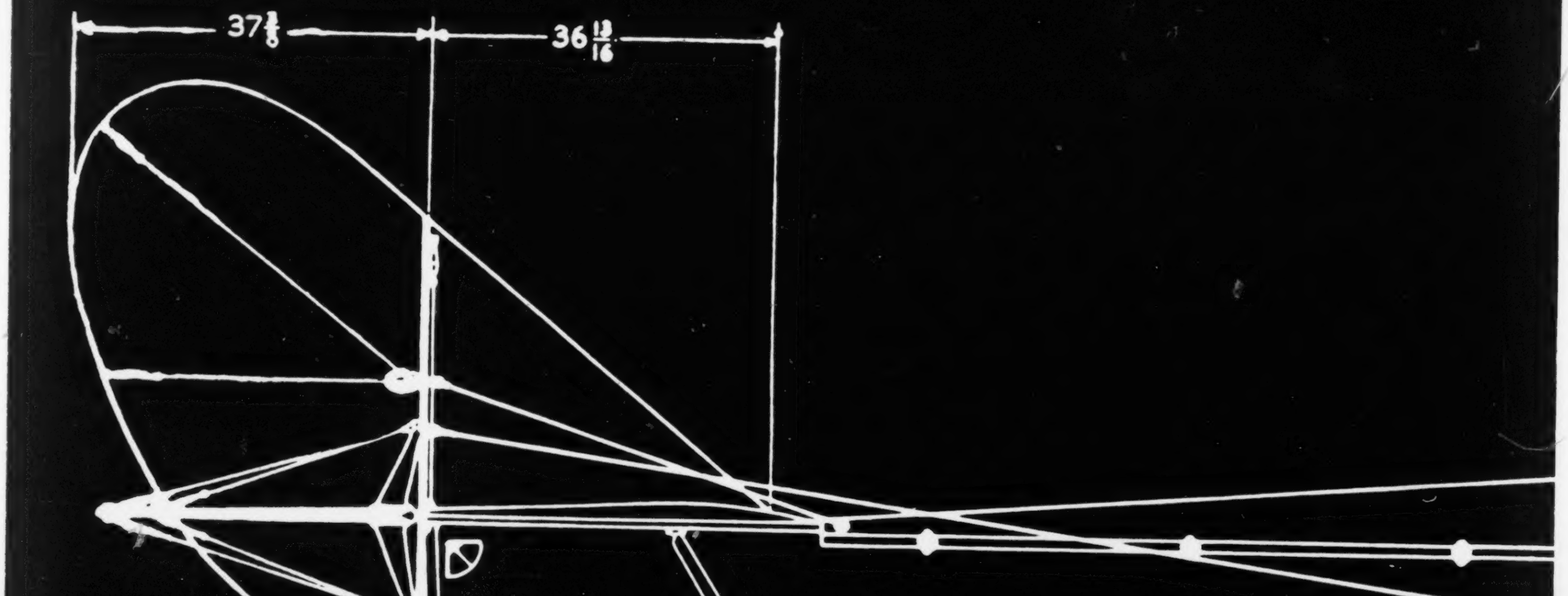

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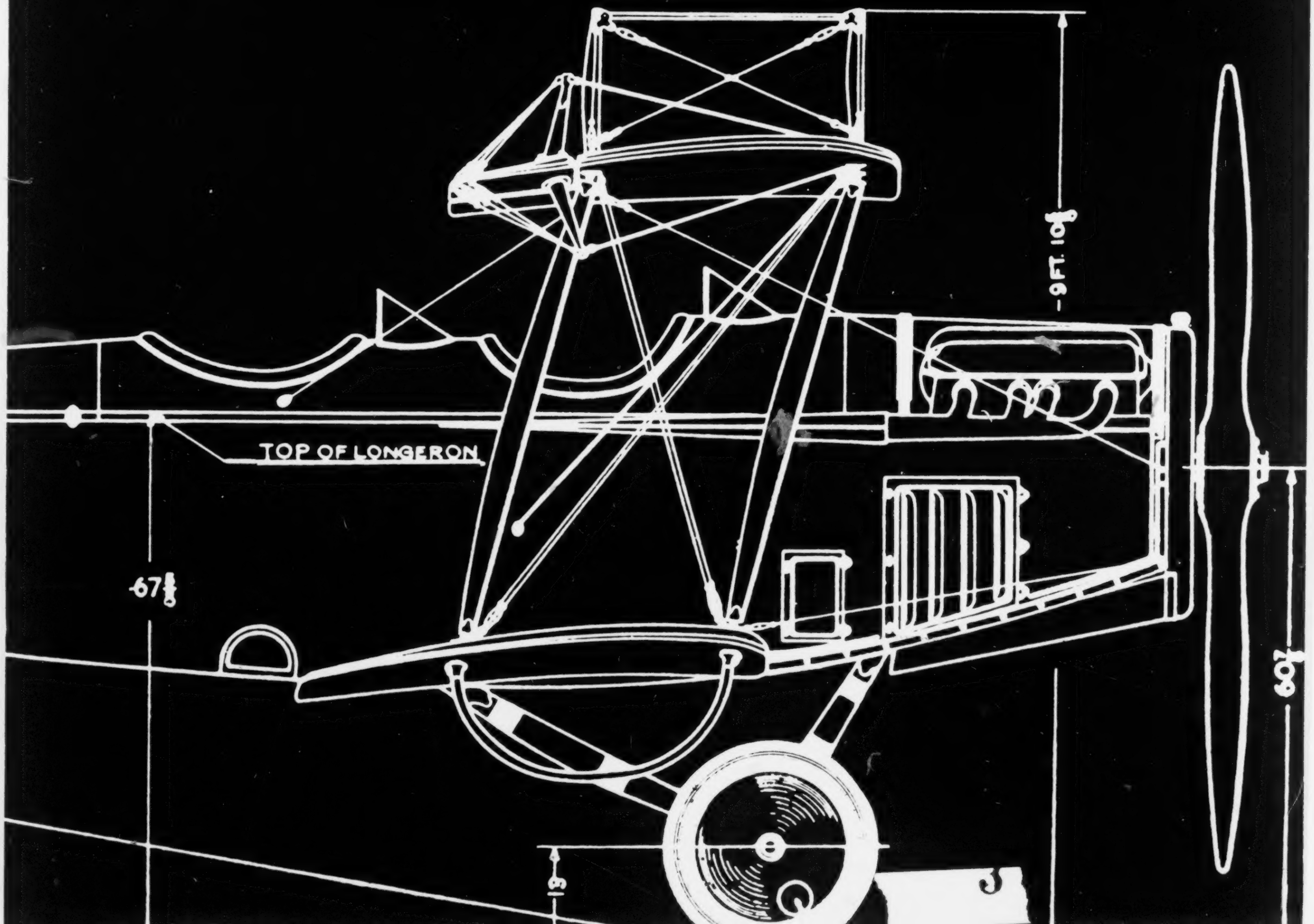
National Advisory Committee for Aeronautics 1917 to 1958
National Aeronautics and Space Administration 1958 to 1967

FIFTY YEARS OF AERONAUTICAL RESEARCH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Introduction

It is fifty years since the first symbolic shovels full of earth were lifted above the soil of Langley Field to signal the start of construction of the first research laboratory for the National Advisory Committee for Aeronautics.

Those shovels of Virginia ground symbolized more than the construction of a research laboratory. They were tangible proof that this country was determined to build an aeronautical research establishment second to none in the world, aimed at regaining and then maintaining the lead in aeronautics which had been given to America by Orville and Wilbur Wright less than 14 years before.

In mid-1917, America had been at war for three months, in a conflict which was to see the airplane grow from a scientific curiosity and a sportsman's plaything to an effective weapon of war.

But when the war broke out in 1914, the United States was last on the list of world powers equipped with military aircraft, running a poor fifth behind France, Germany, Russia and Great Britain.

Not only the tangible evidence of aeronautical progress was lacking. The other powers had seen the value of aeronautical research laboratories and facilities as early as 1866. In that year, the Aeronautical Society of Great Britain was formed to stimulate research and experiment, and to interchange the information gained. Herbert Wenham and Horatio Phillips, members of that Society, invented wind tunnels soon after 1870.

France had major installations: Gustave Eiffel's privately owned wind tunnels at the foot of the Eiffel Tower and at Auteuil; the Army's aeronautical laboratory at Chalais-Meudon; and the Institut Aerotechnique de St.-Cyr. Germany had laboratories at Göttingen University and at the technical colleges of Aachen and Berlin; the government operated a laboratory at Adlershof. and industry was well-equipped with research facilities. Italy and Russia had aeronautical laboratories long before the United States took the step.

National concern mounted as more and more scientifically prominent Americans discovered the woeful position of this country in aeronauttical research. In 1911, it was suggested that the Smithsonian Institution, earlier the supporter of Samuel Pierpont Langley's pioneering work, be given responsibility for an aeronautical laboratory. Objections by both the War and Navy Departments were influential in killing the idea for the time being.

But the Smithsonian pressed its case, and by the following year appeared to have met initial success. President William Howard Taft appointed a 19-man commission to consider the organization, scope and costs of such a laboratory, and to report its findings, along with its recommendations, to the Congress.

An administrative oversight killed this approach; the appointments had been made solely by Presidential action, without the traditional advice and consent from the Senate. The legislation which was proposed to authorize the laboratory failed to get unanimous consent.

The Smithsonian decided to try it alone, and reopened Langley's laboratory. One of the first tasks was a survey of major research and experimental facilities abroad.

The report which came out of that survey showed clearly the dangerous gap between the state of aeronautical technology in Europe and in the United States. Once again, the Smithsonian decided to approach the Congress, and on February 1, 1915, delivered to the Speaker of the House of Representatives a statement which said, in part:

"A National Advisory Committee for Aeronautics cannot fail to be of inestimable service in the development of the art of aviation in America . . . The aeronautical committee should advise in relation to the work of the government in aeronautics and the coordination of the activities of governmental and private laboratories, in which questions concerned with the study of the problems of aeronautics can be experimentally investigated."

That statement became a joint resolution of Congress and was added as a rider to the Naval Appropriations Act approved March 3, 1915. The Act established an Advisory Committee for Aeronautics (The word "National" was to be added later at the first Committee meeting), detailed its organization, apportioned its membership, and described its general task in words which need no improvement today:

". . . it shall be the duty of the Advisory Committee for Aeronautics to supervise and direct the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems which should be experimentally attacked, and to discuss their solution and their application to practical questions. In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories."

The first Committee appointments were made by President Woodrow Wilson on April 2, 1915, and the first full Committee meeting was held April 23.

Among the early projects completed by the Executive Committee of NACA was a facilities survey of industry, government and universities. Out of that work, NACA concluded that it would require both a laboratory and a flight-test facility, the former for model work and experiment, and the latter to work with full-scale problems. With foresight the Committee recognized that building and equipping these facilities ought to be a gradual and continuing process, so that the laboratory could stay abreast of developments in technology.

During 1916, NACA called a meeting of aircraft and engine manufacturers to discuss the problems and progress in airplane engine design and development. That meeting was the first of many to come, and it initiated the close working relationships between the government laboratory and private industry which have existed ever since.

Meantime, the Secretary of War has been told by Congress to survey available military reservations to find one suitable for an aeronautical experimental station, or to recommend a new site, if no existing site were suitable. The Army appointed an officer board which selected a site a few miles north of Hampton, Virginia.

It fulfilled the requirements of the search: It was flat land, fronting on water so that test flights could be made over both land and water. It was east of the Mississippi and south of the Mason-Dixon line, where weather was generally good for flying. It was no farther than 12 hours by train from Washington, D. C. It was not so close to an unprotected coastal area as to be subject to attack or possible capture in the event of war.

A special NACA subcommittee went through a similar search for its own experimental station site, and concluded that the Army's choice was a wise one. The subcommittee recommended that the Army buy the site north of Hampton as a test area for joint Army, Navy and NACA experiments.

That site was to become Langley Field, named after Samuel Pierpont Langley. NACA (which in 1958 became the nucleus of the National Aeronautics and Space Administration) would build its first test center there, but neither the Army nor the Navy would use it for experimental work. The Army would establish its test area at McCook Field, near Dayton, Ohio; the Navy, oriented toward tests of seaplanes, would move its experimental work across the water to Norfolk, Virginia.

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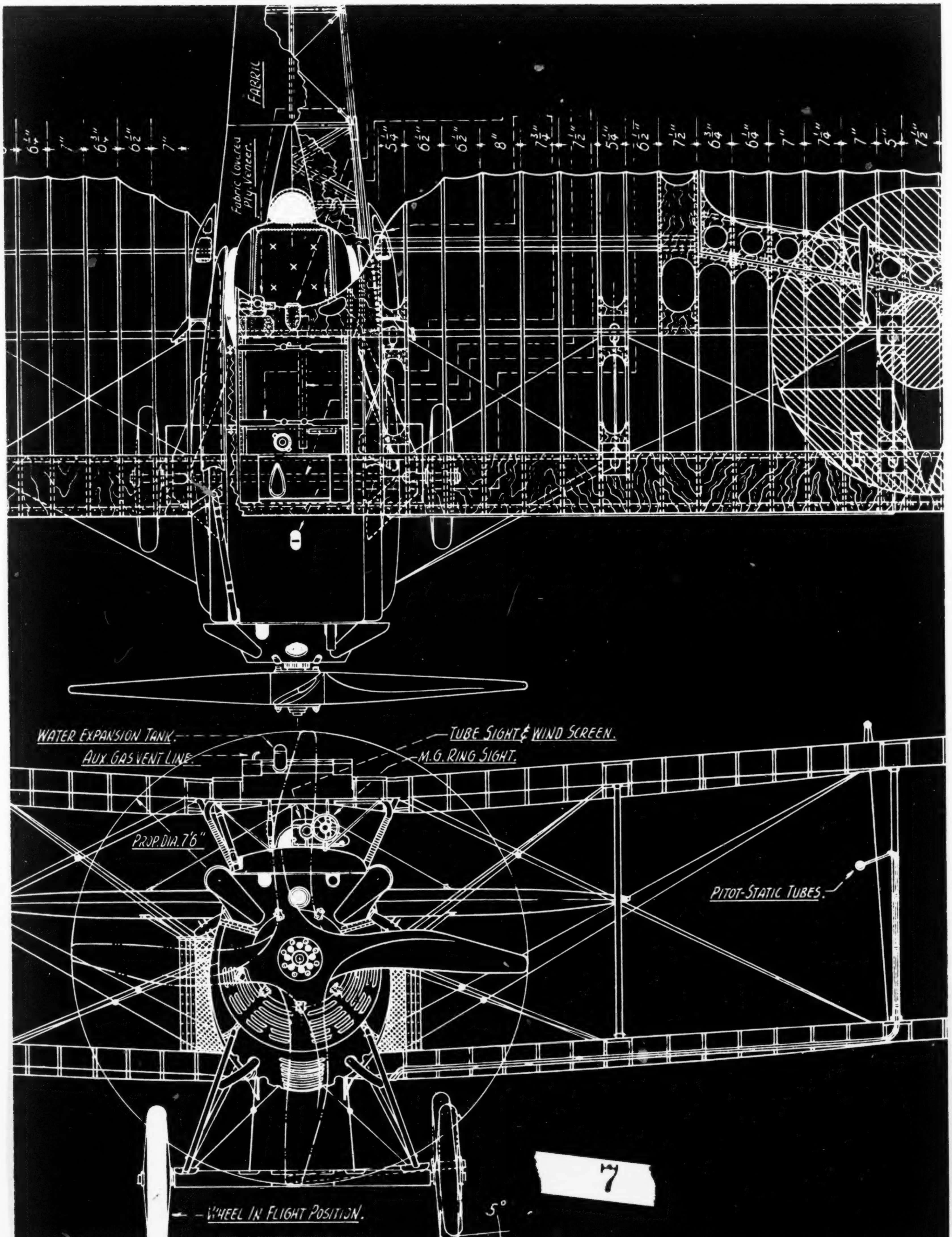
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1917-1927

Langley Research Center, born during the first World War, saw the shaping of the framework of decades to come during its first ten years of life.

The war had introduced day and night bombing. It had spurred the development of bomb sights, automatic pilots, radio communication and navigation aids, self-sealing fuel tanks and pilotless aircraft.

Within three months after the Armistice, commercial aviation started in Germany when Deutsche Luftreederei began its passenger-carrying service. That year also had seen the first daily commercial air service started, with flights between London and Paris. The first international passenger flights from the U. S. followed in 1920; by 1925, regular air freight service had been established between Chicago and Detroit. The new transport industry became subject to its first regulatory legislation, the Air Commerce Act, signed into law in 1926 by President Calvin Coolidge.

Record flights by the score showed the way toward the future routine accomplishments of civil and military aviation. The Atlantic was crossed first by a U. S. Navy Curtiss NC-4 flying boat, and then, non-stop, by Britain's Capt. John Alcock and Lt. Arthur W. Brown in 1919. Four years later, the first non-stop transcontinental crossing of the United States by air was made by Lts. O. G. Kelly and J. A. Macready. In 1924, two of four Army Douglas amphibious biplanes completed a round-the-world flight, another first in aviation history. During the 26,350-mile flight, they flew the first trans-Pacific crossing and the first westbound North Atlantic crossing.

But the most-remembered achievement of the post-war years was the solo crossing of the Atlantic by Charles A. Lindbergh. His history-making flight drew world-wide attention to the potential of the airplane, and gave an impetus to aviation that no other single feat since the Wright brothers' first flight ever has matched.

Other developments during that first decade pointed the way toward the future of aviation. A Curtiss JN-4 was remotely controlled in the air from another JN-4; the Sperry gyro-stabilized autopilot was successfully tested. Inaccessible parts of Alaska were mapped from the air; a Hawaiian forest was planted from the air; cloud-seeding experiments began. Target battleships were sunk by bombing; piped, midair refueling was demonstrated. An all-metal, smooth-surfaced wing was built in Germany by Rohrbach, the progenitor of the stressed-skin structures which are standard today.

And in widely separated parts of the world, Dr. Robert H. Goddard successfully developed and fired liquid-fuelled rocket motors, the German Society for Space Travel (Verein fuer Raumschiffahrt) was organized, and the Russian government established a Central Committee for the Study of Rocket Propulsion.

The problems facing the airplane designer in the early post-war years were difficult. The strutted and wire-braced biplane had high drag, and a low lift-drag ratio. It had poor propeller performance, and an engine—or engines—of low horsepower and doubtful reliability.

Added to this were the complete lack of any means to control the landing speed and the approach angle, the lack of knowledge of gusts and maneuvering loads, and stability and handling characteristics that varied from acceptable to dangerous. It is remarkable that any aviation progress was made.

But it was. The list of technological innovations of this decade is impressive.

It includes the development of a reliable, air-cooled engine; cantilevered design; the use of metal in structures; the concept of tri-motored aircraft; the experimental use of superchargers; the trend to the monoplane; and the development of limited blind flying equipment.

This was the form of the first decade at Langley. It was a ten-year period of startling growth for the airplane, out of its role as a winged weapon of war and into new jobs for the military and a wide range of commercial services.

But the growth had been more accidental than planned. Designers worked with a paucity of data and filled the gaps with their own experience or the experience of others. It was a decade of empirical development, of lucky—and, too often, unlucky—solutions to the manifold problems of airplane design.

It would be the aim of NACA's new aeronautical research laboratory at Langley Field to reduce the element of luck in airplane design, to replace it with a body of carefully developed scientific data, and to point the way to improved airplane design concepts.

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1. One of two Curtiss JN-4H "Jenny" trainers before speed tests, 1919.

2. Sperry M-1 Messenger was evaluated in flight and in the propeller research tunnel.

In the heat of July 1917, excavation began at Langley Field for the first research laboratory to be built for the National Advisory Committee for Aeronautics.

Langley had been authorized as the site for NACA's experimental air station just the month before, and a contract had been let for construction to the J. G. White Engineering Corp., of New York City. Estimated cost of the laboratory was $80,900.

By November 1917, after surveys of existing industry and airfields to determine the state of aviation in the United States, NACA authorized the preparation of plans and specifications for its first wind tunnel. It was to be like the pioneering wind tunnel developed by Gustave Eiffel, with a test section about five feet in diameter and an insert which could be used to reduce the working area to a cross-section with a two-and-one-half foot diameter.

Work began on the tunnel in the spring of 1919, and it was ready for operation one year later.

By then, NACA had proposed a national aviation policy, and among its recommendations was one that research be expanded at the Langley laboratory. NACA also offered the use of its experienced personnel and its new facilities to universities and industry in order to foster aeronautical research and experimental work outside of government laboratories.

The new wind tunnel was operated for the first time at the formal dedication of the Langley Memorial Aeronautical Laboratory, now the Langley Research Center, on June 11, 1920. Visitors to the lab saw a small brick-and-concrete building, from which sprouted two bell-shaped surfaces open at the ends. This was the wind tunnel and the test building.

The test building was about ten by fourteen feet in floor dimensions, and it stood about 23 feet high. Through the center of the building ran the cylindrical test section in which test models were suspended on wires. Below the test section were chairs where engineers sat and read the balance arms of ordinary weigh scales which had been modified to measure the loads on the model during the test.

The tunnel could produce a test section speed as high as 120 mph., believed to be the fastest useful test speed then attainable in the world. Further, it apparently had excellent flow characteristics, compared to its contemporaries, and what were termed "satisfactory means for measuring the forces on models at the highest velocities."

Within six months or so, the Committee authorized construction of a second wind tunnel, a compressed-air unit designed to correct for the scale effect which produced differences between model and full-scale data. Plans were approved one year later and construction was authorized.

The tunnel was designed to run at pressures as high as 20 atmospheres (about 300 psi.), and the test section was to have a five-foot diameter.

The compressed-air tunnel, later to be designated the variable-density tunnel, was operated first at the annual meeting of the full NACA Committee on October 19, 1922. Incidentally, there was not enough electrical power available at Langley to run both it and Tunnel No. 1 concurrently.

The Committee must have been impressed with the growth and stature of the Langley Laboratory at the time of the 1922 meeting. It now was made up of six units:

The research laboratory building, which included administrative and drafting offices, machine and woodworking shops, and photographic and instrumentation labs; two aerodynamic laboratories, each containing a wind tunnel; two engine dynamometer laboratories, one of which was in a permanent building while the other was in a converted hangar; and an airplane hangar on the flying field.

Test equipment included an automatic balance and a high-pressure manometer for the variable-density tunnel, and a special wire balance, for the first wind tunnel, suitable for making tests of biplane and triplane models.

These test techniques and facilities were aimed at measurements of the aerodynamic characteristics of existing aircraft and their components, to devise concepts to improve those characteristics.

But wind tunnels weren't the only test techniques available to the Langley engineers. Within the second year of Langley's existence, work had started on the development of instruments for flight-test work, so that measurements could be made on full-scale airplanes and correlated with data obtained from models in wind tunnels.

That first instrumentation program called for ways to measure engine torque and rpm., propeller thrust, airplane speed and angle of attack. Knowledge of these parameters of a full-scale airplane would both supplement and complement data taken during wind tunnel tests.

This two-pronged approach to the problems of aeronautics—by model tests and by full-scale flight tests—established the interdependence of these two test disciplines early at Langley. Emphasis on that dual approach has been strong ever since, and is one of the foundation stones of Langley research policy today.

By mid-1919, with construction of the first wind tunnel underway at Langley, research was authorized for the first NACA flight tests with full-scale airplanes. The purpose of the tests was to compare in-flight data with wind tunnel data for the

same aircraft to show the degree of correlation, and to determine, if it could be done, a way to extrapolate wind tunnel tests to full-scale results.

The first program used two Curtiss JN-4H "Jenny" trainer biplanes in a detailed investigation of airplane lift and drag. It was the forerunner of a myriad of detailed investigations that would later lead to the development of a series of research aircraft to explore the unknowns of subsonic and supersonic flight.

There was a second important result of that first program with the Jennies. The NACA Technical Report which described the tests also noted that there was a need to develop a special type of research pilot. This was perhaps the first time that the role of the engineering test pilot had been recognized and described.

The faithful Jennies served in a variety of tests during the years. They pioneered inflight investigations of pressure distribution so that designers could calculate the air loads acting on the wings and tail of the aircraft. In the first program, begun in 1920, NACA technicians installed 110 pressure orifices in the horizontal tail of the wood-and-fabric Jenny, hooked to a battery of liquid-in-glass manometers which could be photographed in flight.

Early in January 1921, research was begun to compare the characteristics of wings in model tests and in full-scale flight tests, so that designers could be furnished with complete and accurate data on which to base their performance estimates.

During that same year, new instruments were developed and tested in flight to measure control position and stick forces exerted by the pilot. This was done to understand and improve handling characteristics, and thus increase flight safety. Refined and miniaturized instruments used for the same basic purposes find continued employment today in the tests of high-speed jet aircraft or rocket-propelled research vehicles.

Pressure distribution investigations became a major portion of the flight-test work at Langley. From the measurements of loads in steady-state flight, the work was expanded to study the effects of accelerated flight or maneuvers, because at that time, there was virtually no data available to designers on the distribution of the load on the wing of the airplane in accelerated flight.

Later work extended the pressure-distribution measurements to the nose of a non-rigid airship, first under steady flight conditions, and then during maneuvers over a range of airspeeds and atmospheric conditions.

Five airplanes shouldered the load of flight test work during 1921. Three of them were the Jennies, Curtiss JN-4H types. They shared the flying field with the Lewis & Vought VE-7 and a Thomas-Morse MB-3.

Together, the Jennies logged 110 hr. of flight time in 260 flights during 1921. More than half of the flight time was spent in data collection.

Other pacemaking research began in 1922,

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1. Flight research, 1924: JN-4H, Fokker D-VII, MB-3, DH-4 and Sperry M-1.
2. Thomas-Morse MB-3 joined the Langley test fleet in 1921.

when the first systematic series of takeoff and landing performance measurements was made at Langley. During that year, the Navy Bureau of Aeronautics asked NACA to undertake a comparative study of the stability, controllability and maneuverability of four airplanes: The VE-7, the MB-3, a British SE-5A, one of the most widely used pursuit aircraft in World War 1, and the famous Fokker D-VII, the mainstay of the German Imperial Air Service during the same conflict.

The SE-5 and a De Havilland DH-4 had joined the Langley flight test fleet in 1922, to raise the number to seven aircraft. In addition, four more aircraft were being refitted for test programs or support work: The Fokker D-VII, a Nieuport 23, a S.P.A.D. VII, and a De Havilland 9.

Again the Jenny was used as a test vehicle in 1922 in an extensive investigation of maneuverability. The aim was to find a satisfactory definition of the word, in an aerodynamic sense, and to establish ways of measuring it. Before this time, maneuverability was a subjective judgment by a pilot, full of personal likes and dislikes. The same airplane could be judged light on the controls and maneuverable by a muscular pilot, and heavy on the controls and sluggish by a lesser man.

What was needed was some way of reducing subjectivity to objectivity, and NACA pilots and engineers at Langley set about finding that way.

They instrumented the Jenny to measure its angular velocity following a motion of its controls, as a first approach to defining what maneuverability was.

Like so much of Langley's pioneering work, this early study of maneuverability grew into the extensive flight research work done today on the handling qualities of aircraft. The basic approach laid down then is valid now.

The calibre of the flight-test work being done at Langley began to attract attention from the military services. In 1923, the Navy's Bureau of Aeronautics came to Langley with a request that the Laboratory run a series of flight tests in the low-speed regime on its TS aircraft, a scout aircraft developed by Curtiss. The Navy was particularly interested in accurate determination of the stalling speed, and the takeoff and landing speeds.

The Army Air Service also was concerned with similar questions. The service asked NACA in 1924 to study the acceleration, control position, angle of attack, ground run and airspeed during the takeoff and landing of most of the airplanes then in service with the AAS. The list included the Curtiss JN-6H; the Lewis & Vought VE-7; the De Havilland DH-4B; the Fokker XCO-4, the prototype of the C.IV two-place biplanes then in service with several countries; the SE-5A; the S.P.A.D. VII; the MB-3; the Martin MB-2, a biplane bomber; and the Sperry Messenger.

By then, Langley's flight line sported 11 test aircraft; during 1924 they logged 918 flights for a total of 297 hr. of flight time.

The same year, the Army requested a flight research investigation of the pressure distribution over the wing of a Lewis & Vought VE-7 tandem trainer. The service transferred one of the aircraft to Langley for the program.

The VE-7 soldiered on through other work after that test was completed, including a landmark program using seven different propeller designs, aimed at determining the effects of different propeller design on performance.

Those tests, along with tests with a series of six interchangeable wings, each with a different airfoil section, on a Sperry Messenger biplane, became the first of many NACA comparative tests where a systematic approach was used to develop a better installation or to design a better component.

Sophistication had come both to flight testing and wind-tunnel testing. By mid-1924, NACA was able to make complete pressure distribution surveys, either in the wind tunnel or in flight, in one day of work. Formerly, such tests had required a series of runs over a time period as long as two months.

Later the same year, NACA reported a further refinement in flight testing techniques. Recording instruments had been developed, the Committee said, to make a continuous record of pressure distribution, accelerations, and other parameters during flight tests of aircraft.

During 1925, the flight-test program continued to grow, and there were 19 aircraft in various phases of test work at Langley. They made a total of 626 flights during the year, and logged 245 hr. of flight time.

An engine research laboratory had been started and a dynamometer, to measure output and other performance data on aircraft engines, had been installed in 1919. Since then, a second had been added. Both were kept busy, and so were the powerplant engineers. Early work on superchargers, investigated at Langley in 1924, led to consideration of supercharging to boost engine power for high-altitude bombers, and to obtain a good rate of climb for interceptors. This engine research laboratory later became the nucleus of the Lewis Research Center.

One specific study was made to determine the adaptability of supercharging to an air-cooled engine and its effect on the flight performance of the engine.

Two more pioneering programs were begun at Langley in 1925. The first of these was an attempt to standardize wind-tunnel results, a necessary preliminary to comparison of data taken from two different wind-tunnel installations. NACA engineers developed a series of circular discs which were tested in the Langley tunnel, and then

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sent to other wind tunnels for testing under the same conditions. The results, when compared, offered a way of checking the results of one wind tunnel against another.

Second of these early programs which led the way was the beginning of the measurement of landing loads, even today a major effort at Langley laboratory. But at that time, the loads were to be measured on seaplane floats, so that the specifications for the design of float bracing could be improved.

On May 24, 1926, NACA held its first joint conference with representatives of the aircraft manufacturers and operators at Langley. It was the first of what was to become a recurring event and a great NACA tradition: the inspection tour. But it went further; it provided the guests with an opportunity to criticize current research and to suggest new avenues they believed promising.

The second of these conferences, held the following year, was expanded to include representatives of educational institutions that taught aeronautical engineering, and of trade journals that played such an important part in the dissemination of aeronautical information.

This interchange of information between industry and NACA, always one of the major factors in directing the course of the Committee's research, has been maintained over the years since the first formal joint conference in 1926.

By that time, the outstanding work of the Langley Laboratory had also been recognized by foreign institutions. Typical of that recognition was a request from the Aeronautical Research Committee of Great Britain, which asked Langley to run a series of wind-tunnel tests on three airfoil sections, incorporated in wing designs on three different aircraft models. The results were to be used for comparison with wind-tunnel and full-scale flight results previously obtained in England.

One of the more significant developments in aeronautical research to grow out of the Langley laboratories had its beginning in a letter sent from the Navy's Bureau of Aeronautics in 1926. The Navy had been convinced that the air-cooled engine was a more practical solution to its powerplant problems than the liquid-cooled powerplants favored by the Army. But Navy engineers were well aware that air-cooled installations had more drag and wasted more power in cooling the engine than seemed necessary. The engineers believed there was some way to put a streamlined cowling around the engine to reduce

2

1. Ford truck, Huck starter, and Lewis & Vought VE-7, around 1924.
2. War booty, this German Fokker D-VII was tested at Langley in 1922.

its drag and improve its cooling performance, and they asked Langley to investigate the possibilities.

A similar request came out of the second industry-NACA meeting. Industry engineers, obviously up against the same problem the Navy faced, turned to NACA for help. They asked that the effect of the fuselage shape on cooling and cowling also be taken into account, in addition to the effects produced by whatever optimum cowling shape the laboratory was able to devise.

Model work in the one remaining wind tunnel—the variable-density tunnel had been badly damaged by fire in August 1927 and was out of action for two years—wasn't the answer. The models were small, and were tested without propellers. Flight test would be too costly, and too time-consuming, but it looked like the only way possible at the time.

The final answer was to come from the propeller research tunnel, a brand-new piece of equipment authorized two years before and scheduled to start operation at the end of 1927. Originally planned to be able to test full-scale propellers under simulated flight conditions, the tunnel also was to be used for the testing of full-scale fuselages or tail surfaces, or of large model wings. With its 20-ft. diameter test section, and its top wind velocity of 110 mph., it was not only the largest wind tunnel in the world, but also the first in which the major components of a full-sized airplane could be tested.

With the availability of this new research tool, Langley had come of age. Its first ten years of life had been devoted largely to exploring and identifying the problems of aeronautics.

The years had been used to develop the organization, to build facilities, to survey the industry and the operators of aircraft to determine what kinds of problems needed solutions.

Along the way, problems were solved, and major contributions were made to the aircraft designs of the day. But the major contributions of Langley during its first ten years of life were made to itself and to the National Advisory Committee for Aeronautics, to their functioning and growth, to give them the ability to understand the problems of flight and to be ready to find solutions to them as the need for those solutions grew more and more pressing.

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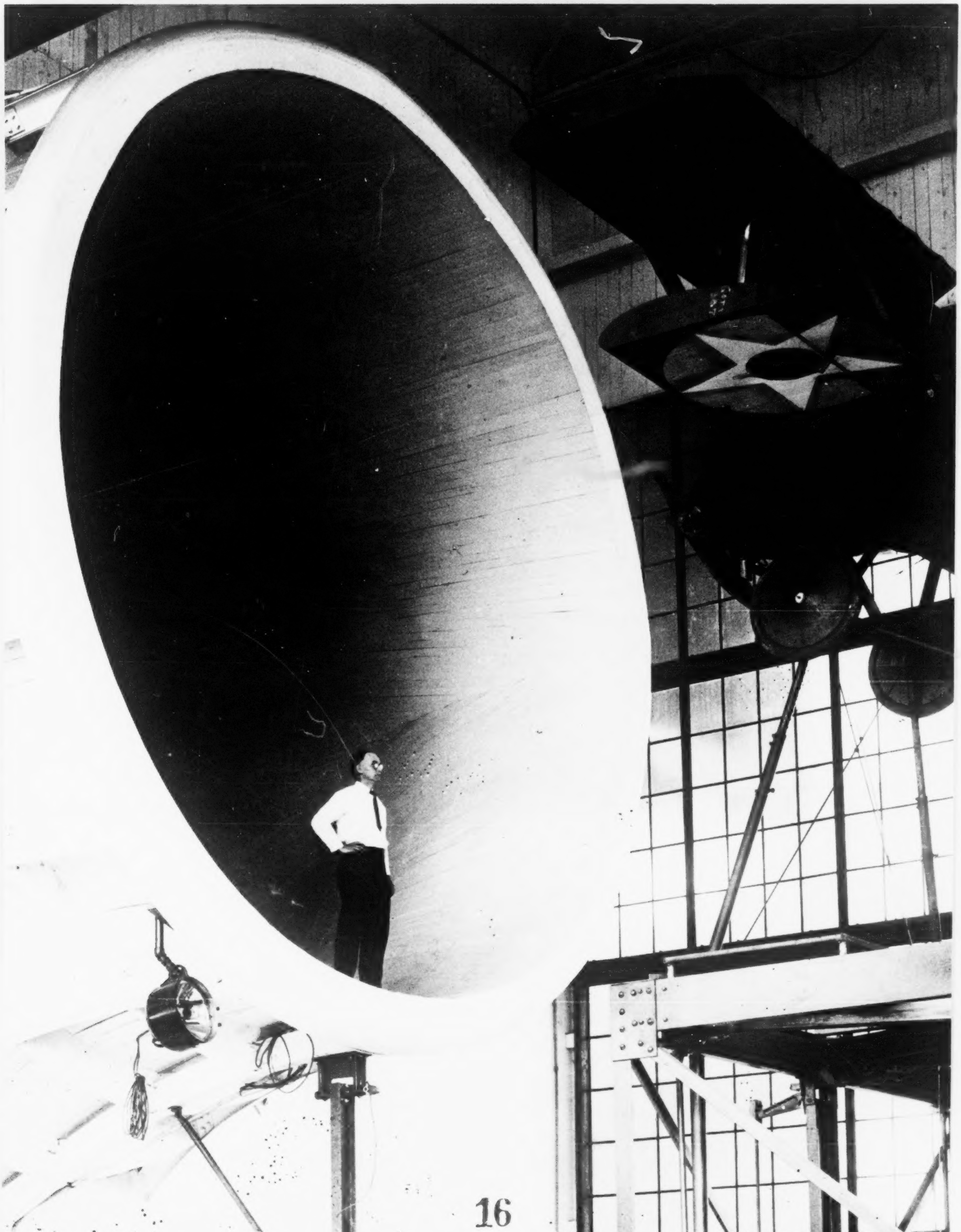
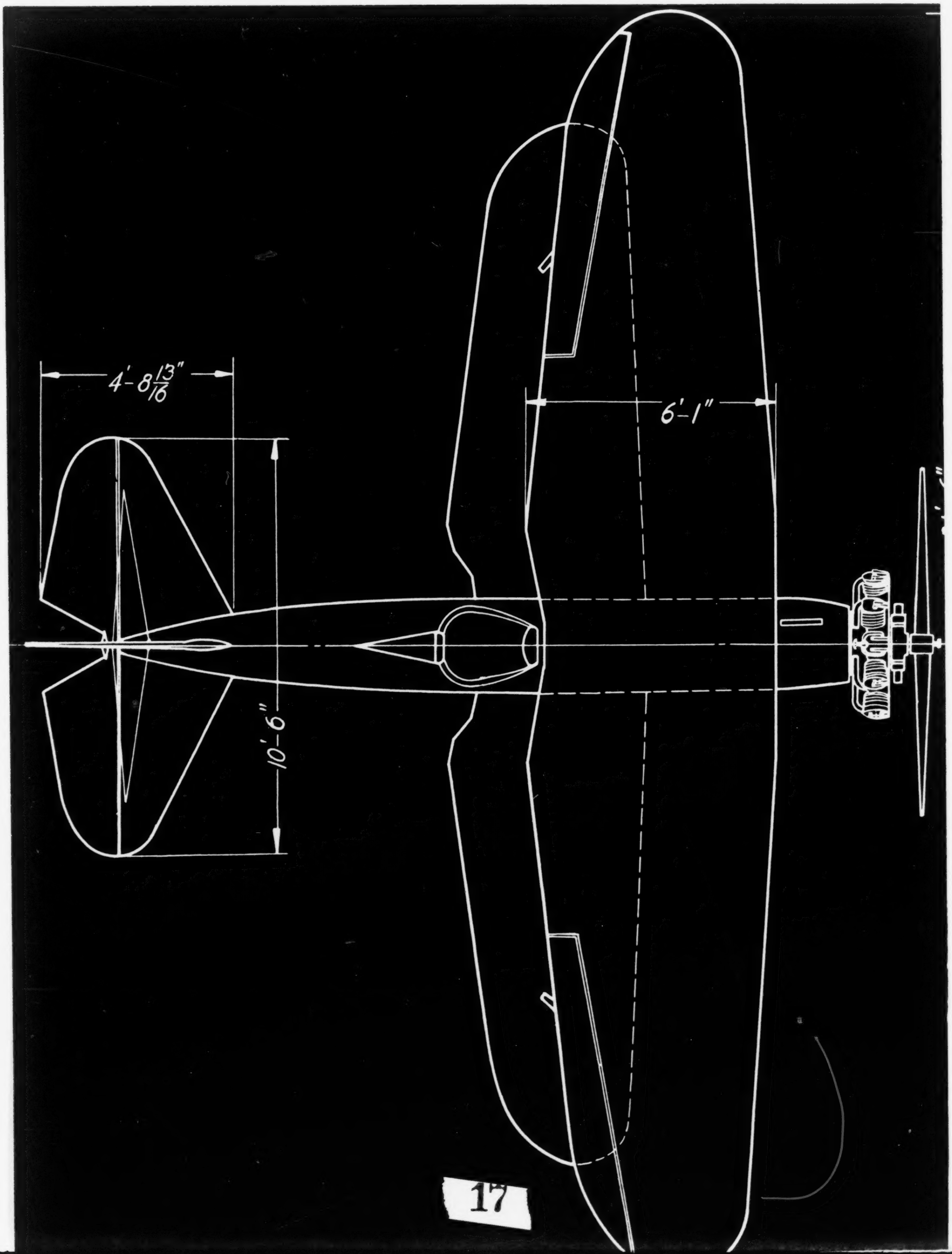
Sperry M-1 Messenger was first full-scale airplane tested and one of first test programs in the propeller research tunnel, in mid-1927.

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1928-1937

The second decade of work at the Langley Memorial Aeronautical Laboratory began on the upsurge of a new wave of popular interest in aviation. Lindbergh's historical crossing of the Atlantic had touched the imagination of the world, and had converted skeptics into believers.

This decade would produce a revolutionary change in the appearance and performance of airplanes, firmly establishing their position in the growing transportation networks of the world and guaranteeing their future predominance in that field.

In commercial aviation, Transcontinental & Western Air inaugurated the first coast-to-coast through air service in 1930, between New York and Los Angeles. The Boeing 247 and the Douglas DC-1, progenitors of long lines of transports to come and of years of commercial rivalry between the companies, made their first flights during 1933. The following year, Douglas started work on the DC-3, the plane that was to revolutionize air transport. It first flew in 1934.

That same year, Pan American started survey flights with flying boats across the Pacific and followed with the start of air mail service from San Francisco to Manila. In 1936, the airline carried the first passengers on its new trans-Pacific route. In 1937, Pan Am and the British carrier, Imperial Airways, made survey flights across the Atlantic, and Pan Am started the first air mail service between the United States and New Zealand.

During the decade, Boeing's Model 299, the prototype of its B-17 "Flying Fortress" series, made its first flight (1935). In Britain, the prototype Hawker "Hurricane" flew for the first time, and the first report on radio detection and ranging (radar) was presented to the British Air Defence Research Committee.

Three wars, which led to an increased appreciation of airpower, erupted during this period. Japan began its operations against China in 1931; Italy declared war on Abyssinia in 1935; the Spanish Civil War began in 1936.

The tragic Spanish conflict drew other nations to the fighting within Spain's borders, and gave them the opportunity to test and develop new weapons and concepts. Guernica, the seat of the Basque government, was bombed and devastated by German aircraft in a demonstration of things to come.

The decade saw the death of the dirigible following a series of tragic accidents to the British R-101, the U. S. Navy's Akron and Macon, and the German Hindenburg.

Some of the most radical developments of the ten years took place in jet propulsion. The year 1928 saw the first rocket-powered glider flight made in Germany, and the publication of a fundamental paper on jet propulsion by Frank Whittle. Nine years later, his first engine was run. The Russians published the first volume of a nine-volume encyclopedia on interplanetary flight that year.

In 1929, the first known use of jet-assisted take-off was successfully demonstrated in Germany.

The following year, the German Verein fuer Raumschiffahrt established a test site in Berlin, and the German Army Ordnance Corps organized its rocket weapon program and moved it into a test station at Kummersdorf.

Static tests of a Heinkel He-112, converted to be flown with an auxiliary rocket engine, were made in mid-1935, and the airplane made its first successful test flight early in 1937. It was the forerunner of later German developments in rocket-powered fighters.

In 1937, German Army Ordnance opened its rocket development station at Peenemunde. In Russia, three rocket test centers were established near Moscow, Leningrad, and Kazan.

The biplane was the standard design when NACA's Langley Memorial Aeronautical Laboratory started its second decade of life. The Army Air Corps' newest bomber was the Curtiss "Condor", a twin-engined biplane with fixed landing gear, strut bracing, open cockpit and a biplane tail assembly. Its hottest fighter was another Curtiss product, the P-1 series, progenitor of a long line of Curtiss "Hawks." It too was a biplane, with strut bracing, fixed landing gear, and a liquid-cooled engine.

The commercial airways were served by the tri-motored monoplane Fords, an all-metal high-winged design, the Boeing 80 biplanes, also tri-motored, and various single-engined designs such as the Fokker Universal.

In most of the commercial and military designs, the basic airplane was a strut-braced and wire-braced biplane, built of wood or steel tubing, and covered with fabric. Its landing gear was fixed; its engine, if aircooled, was uncowled. The propeller was a fixed-pitch type. The monoplane *design had been established, but in most instances as a strut-braced layout. Its designers were unsure of the problems of flutter and aeroelasticity.*

By the end of this second decade, the biplane was almost as dead as the dodo. Military and commercial craft were internally braced, unstrutted monoplanes, with sleekly cowled engines, retractible landing gear, and wing flaps. The design revolution of the early 1930s had been sparked by developments at Langley.

The propeller research tunnel, which began operating in 1927 at the end of Langley's first decade, began to pay off its investment in the earliest years of the second decade.

For the first time, an aeronautical laboratory had a research wind tunnel big enough, and versatile enough, to test full-size aircraft components. There was an additional benefit; the scale of testing was physically large enough so that tiny components, which would have been nearly invisible on the small wind tunnel models previously used, could be evaluated. This was to make possible a whole new world of test studies that would result in detailed refinement of many aircraft to come.

The first program in the propeller research tunnel was directed toward the problems stated by the Navy and industry earlier: The reduction in drag and improvement in cooling efficiency of an air-cooled engine.

The result, after systematic wind tunnel testing, was the construction and installation of an NACA-designed cowling on a Curtiss AT-5A advance trainer of the Army Air Corps. The NACA Annual Report for 1928 said that "... the maximum speed was increased from 118 to 137 mph. This is equivalent to providing approximately 83 additional horsepower without additional weight or cost of engine, fuel consumption, or weight of structure. This single contribution will repay the cost of the Propeller Research Tunnel many times."

The Wright R790-1 air-cooled engine which powered the AT-5A was rated at only 220 hp. The additional equivalent of 83 hp. was a staggering boost in available engine power, or an equally staggering reduction in engine drag, depending on the viewpoint of the designer.

NACA received the 1929 Collier Trophy award for the development of the cowling. The Trophy, an annual award for the greatest achievement in aviation in the United States, was presented in 1930 to Dr. Joseph S. Ames, then NACA Chairman, by President Herbert Hoover.

The design revolution had begun. The NACA cowling was to become the standard enclosure for air-cooled radials, and was to be continually revised and improved in the future. The dramatic reduction in cooling drag produced by the cowling led designers to ask for, and NACA to look for, other areas where drag could be reduced substantially.

One obvious source of drag was the fixed landing gear, long recognized as a prime producer of built-in headwinds. The Sperry Messenger was tested in the propeller research tunnel, and its fixed landing gear was found to account for nearly 40 percent of the total airplane drag. These measurements were the first to pinpoint the exact amount of drag caused by the landing gear, and the first to show the performance penalty incurred by not retracting the gear.

Still working in the interests of drag reduction, NACA engineers looked at a tri-

1. Army Curtiss AT-5A was first airplane fitted with NACA cowling: 1928.

2. Langley metal workers fabricated NACA cowlings for early test installations.

U.S. ARMY
CURTISS AT-5A
A.C.28-66
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motored Fokker transport powered by Wright J-5 Whirlwind powerplants. Cowling these engines, they reasoned, should make a substantial improvement in the performance of the airplane. But it didn't, and they began to wonder why.

The wondering led to the belief that maybe the awkward powerplant installation had something to do with it. The standard design of the period was to support the engines above or below the wing on a strutted structure, whose dimensions were determined by eye rather than by any aerodynamic considerations.

Studies in the propeller research tunnel soon showed there was an optimum position for engine nacelles, and it wasn't above or below the wing. The optimum was for the nacelle to be faired into the leading edge of the wing; the improvement again was marked.

Meantime, NACA had been conducting systematic investigations of propellers, of airfoil sections, of high-lift devices, of interference drag between fuselage and wing, or fuselage and tail. Wing fillets were developed, and reported in a 1928 Technical Note. Even the drag of small fittings, such as a protruding gasoline tank filler cap, could be measured and its effect on performance assessed.

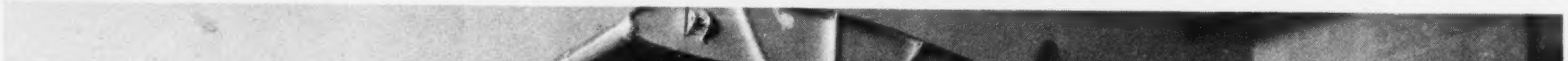
The quiet revolution was well underway. For the first time, designers could build a "clean" airplane, could estimate its drag and performance more accurately, and could understand the possibility of a small change causing a major increment in performance.

The availability of the NACA cowling, propellers of increased efficiency, more efficient airfoils, wing fillets, and knowledge of the mechanism of drag led directly to the change in design from the strutted biplane to the sleek monoplane.

No longer could a designer argue that it wasn't worth the weight and complexity to retract the landing gear for those few miles per hour. The aerodynamicists could tell him that those miles per hour weren't few, and that retracting the gear could mean the difference between winning and losing a contract.

Even before the NACA cowling had been completely developed in the propeller research tunnel, NACA realized that a full-scale tunnel would be a necessity. Airplanes would be bigger than the 20-ft. throat test section of the PRT, and the work load of full-scale airplane testing was bound to increase as soon as industry and the military realized the advantages of such test work.

The need for the full-scale tunnel was first outlined in a letter from Dr. Ames to the Director of the Bureau of the Budget. Construction began in January, 1930, and the tunnel was officially dedicated at the sixth annual conference in May, 1931.



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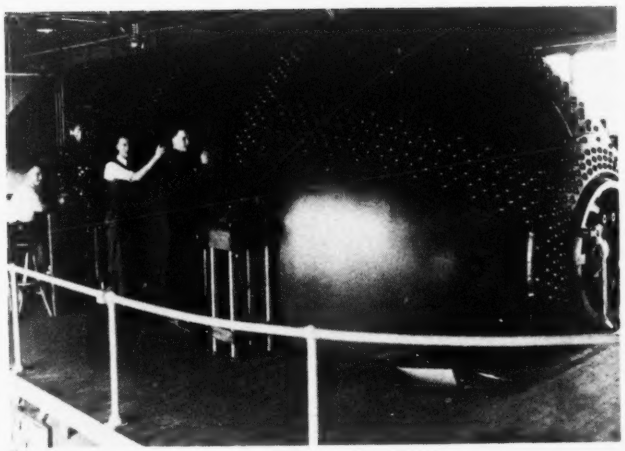

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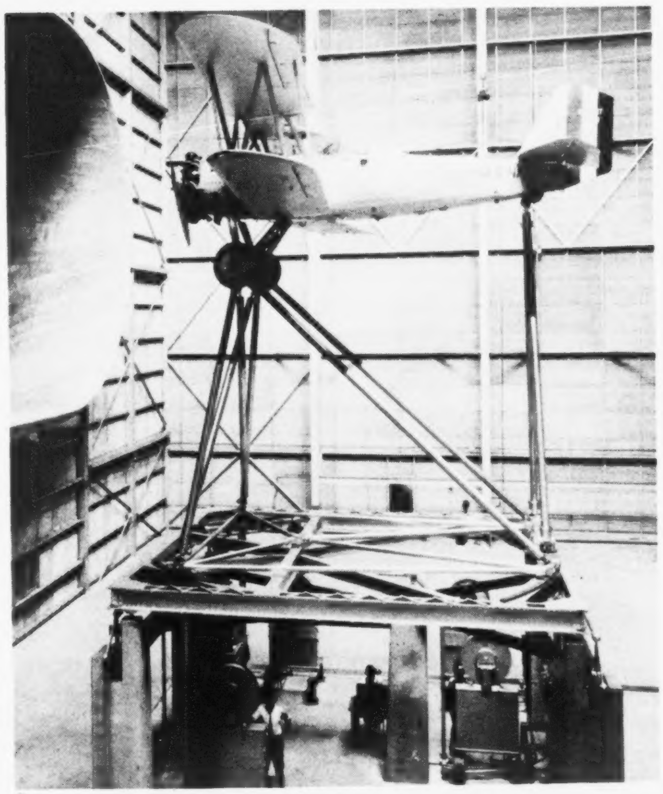
1. Langley's variable-density tunnel, damaged by fire in 1927, was photographed in March, 1929, when tests began again.

2. Military aircraft of the decade, shown during tests in the full-scale tunnel at Langley: Boeing PW-9 of 1925.

3. Vought 03U-1, in 1931 the first complete airplane to be tested in the full-scale tunnel.

4. Douglas XO-31 of 1930.



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Other research facilities at Langley grew out of specific needs. Some research work had been done in 1927 on the prevention of aircraft icing by thermal systems, but the study had been completed without further action. Early in 1928, the Assistant Secretary of Commerce for Aeronautics called a conference of military and government agencies, including NACA, to study the causes and prevention of ice formation on aircraft. A few days earlier, the Navy's Bureau of Aeronautics, frequently a pioneer in defining a problem area, had asked NACA to determine the conditions under which ice forms on an aircraft, and to develop some means of prevention.

The result was NACA's first refrigerated wind tunnel, which began operations during 1928. Its aim was to study ice formation and prevention on wings and propellers of aircraft, and its tests pointed the way toward the successful development of schemes to prevent, or remove, ice accretions.

These studies grew into a major effort that later won another Collier Trophy for an NACA scientist. Lewis A. Rodert, who began his NACA career at Langley, won the 1946 trophy "for his pioneering research and guidance in the development and practical application of a thermal ice-prevention system for aircraft."

Rodert conducted most of his basic research from 1936 to 1940, during which time he was in the Flight Research Division of Langley. He transferred to the Ames laboratory in 1940, and was Chief of Flight Research at the Lewis laboratory when he won the Collier Trophy.

In 1928, the Army's experimental flight-test facility at Wright Field had begun a series of tests to determine the spin characteristics of aircraft. Two years later, Langley had started to operate a free-spin wind tunnel, in which models could be spun in a manner simulating the dynamics of full-scale, free flight.

This led to the construction of a larger spin tunnel, with a 15-foot throat and adjustable airflow velocity so that the model could be held at one position in the throat and observed visually from outside the tunnel.

The success of this type of wind tunnel led NACA directly to the more complex free-flight tunnel, a major research tool which has given birth to a range of test techniques used with models of today's aircraft.

The first of Langley's hydrodynamics test tanks was completed in 1931, to serve the research needs of the seaplane and amphibious airplane designers. The wind tunnels would provide aerodynamic behavior of the aircraft; the test tanks would analyze the behavior of models on the water in an analogous manner.

The tank was 2,000 ft. long, although later extended to 2,900 ft., and was used primarily to determine the performance characteristics of hull shapes. By towing the model hull through the water from a standing start to a simulated takeoff speed, Langley scientists could determine the hydrodynamic performance of the hull and suggest changes or improvements in the basic design.

The tow tank was used also for systematic development of families of hull shapes. In later years, a second tank, 1,800 ft. long, was built. In that tank, simulated forced landings on water would be done with landplane models, and still later the Mercury, Gemini and Apollo water-landing techniques would be checked out using the same tank.

At the time when airplanes were routinely logging speeds of less than 200 mph., NACA was looking ahead to the future where speeds up to 500 mph. might be possible. Late in 1933, NACA outlined its needs for a 500-mph. wind tunnel, called then the "full-speed" tunnel, and estimated its cost at under a half million dollars in a letter to the Federal Emergency Administration of Public Works. Construction of the tunnel was completed in March, 1936, and it began operations in September that year. Its test section had an eight-foot diameter, enough to investigate large models of aircraft and some full-scale components.

The eight-foot tunnel was to become a pioneering tunnel in high-speed aerodynamic research in this country, and was to be the foundation of the future structure of Langley's brilliant work in the high subsonic speed range and on into the mysteries of the transonic region.

Other pioneering facilities were designed and started during this second decade. The 19-foot pressure tunnel construction contract was awarded early in 1937, and late that year the first low-turbulence wind tunnel entered construction.

The 19-ft. tunnel was a leader in propeller research, because it could test a full-scale propeller in a close approximation of its operating range.

The low-turbulence tunnel was to become the source of the NACA low-drag (laminar flow) airfoil.

Still closely coordinated with the aerodynamic work at Langley was the job of flight research. A new kind of aircraft called an autogyro had been flown in the United States for the first time in 1928. This was the first departure from the fixed wings of the basic Wright brothers design, a radical approach providing lift by using rotating wings.

During 1931, Langley bought a Pitcairn PCA-2 autogyro and started its work on rotary-wing aircraft. The PCA-2 was instrumented and test-flown. Its rotor was tested in the full-scale wind tunnel for correlation between tunnel and flight tests, and a model of its rotor was tested in the propeller research tunnel to determine scale effects. A camera was mounted on the hub of the rotor to photograph the blade behavior during flight.

The flight tests of the PCA-2 included some measurements during severe maneuvers, with results still applicable to the fast-moving helicopters of today. That particular autogyro had a fixed wing surface to carry some of the weight of the aircraft in normal forward flight. The flight tests made at Langley included some work in which the incidence of the wing was varied, so that it carried a different proportion of the aircraft weight in each of a series of tests. These experiments indicated some of the problems faced today by designers of high-speed helicopters, who want to unload the rotor by using a fixed or variable wing surface to generate additional lift.

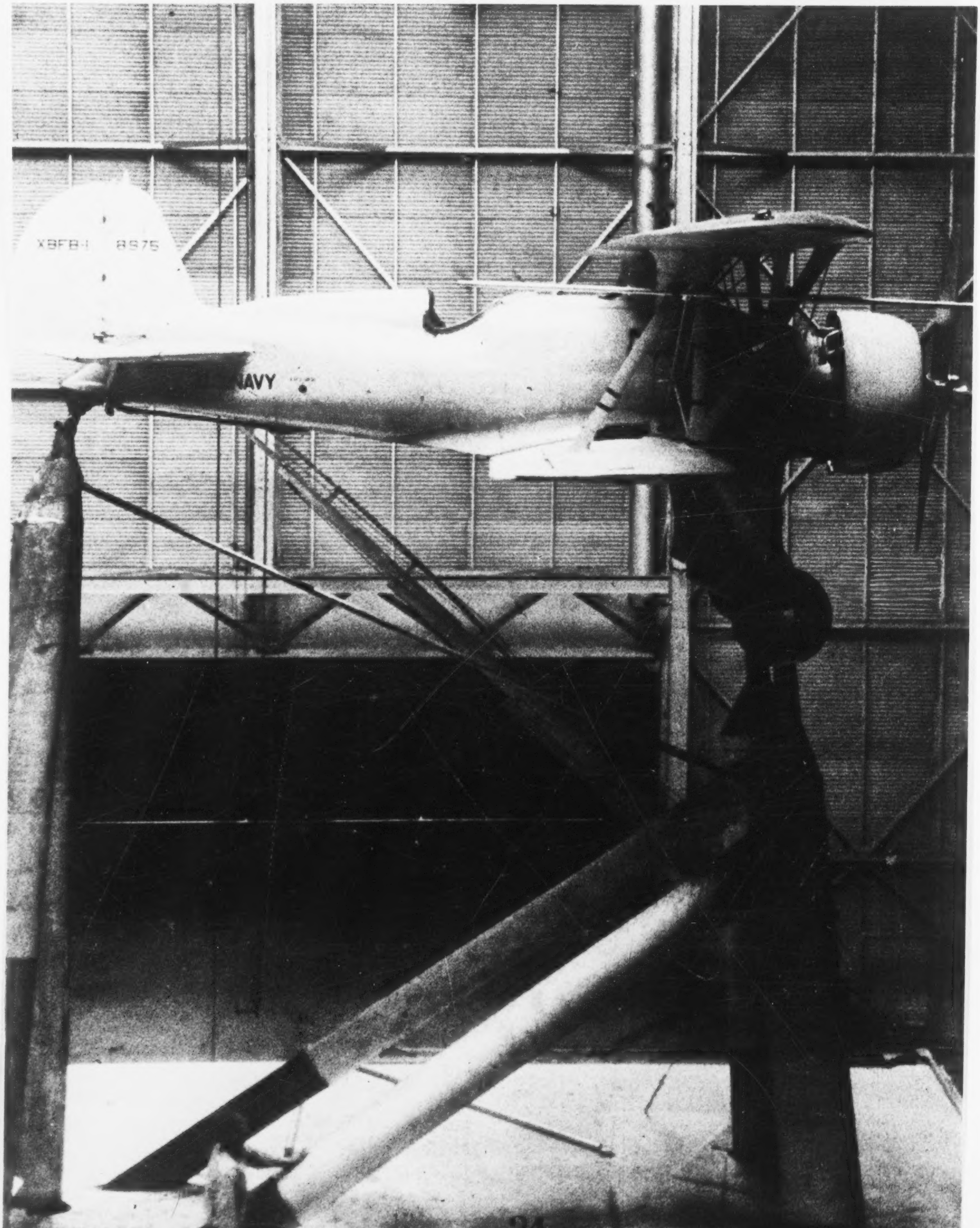
This was the first major project accomplished by the rotary-wing research group, a small unit which has been maintained throughout the years to specialize in the problems of rotary-wing systems.

Flight research was maturing rapidly. During 1931, a landmark report was published. NACA Technical Report 369, titled, "Maneuverability Investigation of the F6C-3 Airplane with Special Flight Instruments", was the first published report which dealt with the handling qualities of aircraft, a task that has occupied many of the Langley and other NACA/NASA personnel to this day.

In 1932, the flight research laboratory was officially opened. It was a separate area, with hangar space for aircraft, its own repair shop, and office space for the staff.

During 1933, the forerunners of two great families of airliners first flew: The Boeing 247 and the Douglas DC-1. Both were radical departures from their predecessors; both were all-metal, low-winged craft, with cowled, air-cooled engines and retractable landing gear. They had two

Boeing XBFB-1 of 1934,
last of the fixed landing-
gear military aircraft.


XBFB-1
8975
NAVY

Boeing P-26 of 1935 during flap development work.

engines instead of the more-common trimotored arrangement. With both engines operating, performance was outstanding. But if one engine failed, the available power was halved, instead of being reduced only by a third.

The engine-out situation became a primary concern of industry, and Langley was asked in mid-1935—six months before the Douglas DC-3 first flew—to evaluate the handling and control characteristics of a twin-engined airplane with one engine inoperable. The program had been suggested by the Douglas Aircraft Co.

Other research paralleled the aerodynamics and flight work. A new engine lab had been opened in 1934, and began to play an important part in powerplant development. Part of the workload was directed toward solution of existing problems, generally associated with the cooling of air-cooled engines.

But some of the research was aimed at finding out the fundamentals of the internal combustion engine, a type of powerplant that had been operating for years without any real understanding of what went on inside its cylinders.

NACA wanted to find out, and initiated a series of research programs on the fundamentals of fuel ignition and burning. Goose down was used to show the air flow patterns of air and mixed gases inside a cylinder, and the motions were stopped by high-speed cameras developed at Langley.

Research on aircraft structures was the province of a handful of engineers at Langley. Yet out of the very early years grew a program that is still active today, and a basic research instrument that is installed on fleets of military and civilian aircraft flying at this moment. It started as a V-G recorder, to measure the vertical accelerations experienced by an airplane flying in rough air. The aim was a simple one: To gather statistical data about air turbulence, its frequency and intensity, and from that data, to evolve criteria for design of aircraft.

Today, a sophisticated form of recorder is installed in aircraft of all types and sizes and performance capabilities, from single-engined private planes to the eight-engined jet bombers of Strategic Air Command. The wealth of data is analyzed by computer techniques, and continues to expand the range of man's understanding of the phenomena of flight.

By the end of the second decade, the design of aircraft had changed for all time. The all-metal, low-winged transport ruled the airlanes, and its sister ships made up the bulk of the military air fleets.

One of the newest military craft was the Boeing Model 299, prototype of the B-17 "Flying Fortress" series, which had flown in mid-1935. In its early flights it surpassed predictions and expectations, and Boeing went on record with a letter to NACA which said, in part:

"You may recall sending us, some time ago, the data which you had obtained on the so-called 'balanced flap'. It appeared to give such promising results that we decided to use it on our model 299 bomber.

"We were also much gratified to find that the NACA symmetrical airfoil lived up to our expectations. It appears that in addition to the effectiveness of the flap, the ailerons are more effective, for a given area, than with the conventional airfoil.

"So, with the use of the NACA cowl in addition, it appears your organization can claim a considerable share in the success of this particular design. And we hope that you will continue to send us your 'hot dope' from time to time. We lean rather heavily on the Committee for help in improving our work."

But in spite of the enthusiasm of such endorsements of the work and contributions of NACA, a nagging feeling had persisted that more could be done. The possibility existed that other countries were making more positive contributions to their aeronautical industries than NACA was making to the industry of the United States.

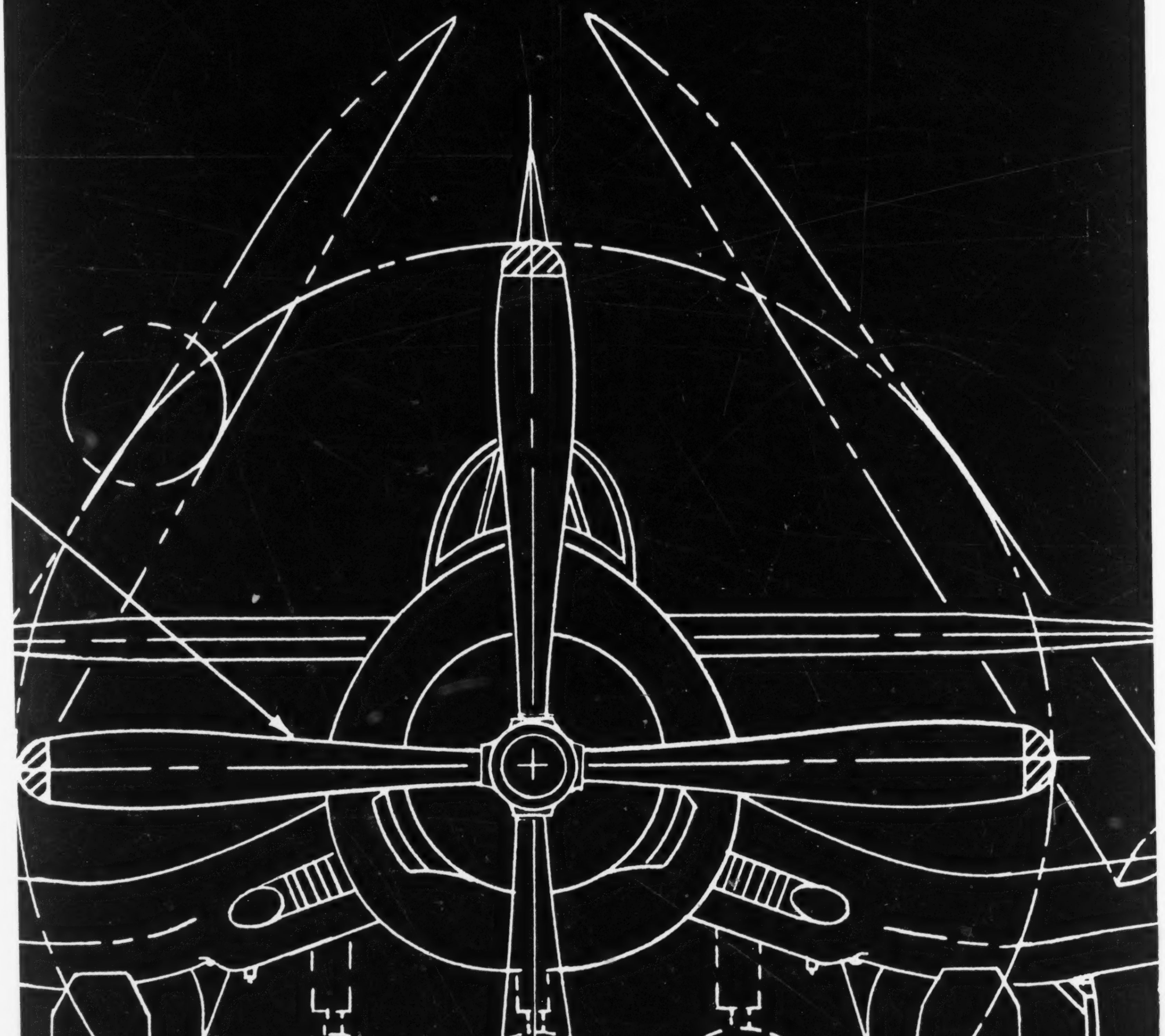
The scientific challenge to the aeronautical research supremacy of the United States had been recognized and was voiced strongly in the 1937 Annual Report of the Committee to the Congress and the President of the United States. The report explained that, up until 1932, the laboratories at Langley were unique in the world, and were one of the chief reasons that this country was the technical leader in aviation.

But since then, much of that equipment had been duplicated abroad and, in some cases, had been bettered so that Langley's equipment was no longer the best.

The report went on: "This condition has impressed the Committee with the advisability of providing additional facilities promptly as needed for the study of problems that are necessary to be solved, in order that American aircraft development, both military and commercial, will not fall behind."

For some time, the warning went unheeded; Langley and NACA continued to work under pressure, making do with facilities and equipment that were beginning to show their age. There was no particular reason to improve the laboratories, no overwhelming problem that couldn't be handled in the ordinary routine of NACA's working day. In a way, the attitude reflected the general American view toward all world problems, not just the specific problem of maintaining aeronautical leadership.

The war in Europe was far away; this country was beginning to pull out of the crushing depression of the early part of the decade. Things looked reasonably good, and who really cared if foreign scientists were testing rocket motors or developing dive bombers? What difference did a supersonic wind tunnel in Italy make?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1938-1947

World War II dominated the third decade of Langley's work. It broke out in September 1939, and before it was concluded officially in September, 1945, the shape of aircraft had been changed again.

A handful of technical developments caused this second revolution in aircraft design. Sweepback, an aerodynamic innovation discovered almost simultaneously by several investigators, was exploited in advanced fighter and bomber projects by German engineers.

Jet propulsion, another example of parallel discovery and development, made great strides during the war. The first aircraft powered by a turbojet was flown in Germany on August 27, 1939; both Germany and Britain had operational jet-propelled fighters before the war ended.

Rocket development was paced by the demands of war. The first German V-2 (A4) ballistic missile was fired unsuccessfully twice in 1942 before its first successful launching in October that year. It was to become operational as a field weapon less than two years later, only a few months after the pulse-jet powered V-1 flying bomb was used to bomb London.

Guided missile warfare started in August 1943 with the German use of radio-controlled rocket-powered glide bombs against ships.

Nuclear weapons were conceived, developed, tested and used operationally during World War II, culminating in the bombs dropped on Hiroshima and Nagasaki.

Missiles as defense weapons received their first impetus when Project Nike was originated in February 1945, to strike at high-altitude, high-speed bombers that would be coming into service.

The destruction of war gave way to the pursuit of more peaceful aims in aviation after the surrenders in 1945. Landplane speed records were shattered, first by the British who moved the mark over the 600-mph. point with Gloster Meteors basically the same as those used operationally by the Royal Air Force near the end of the war.

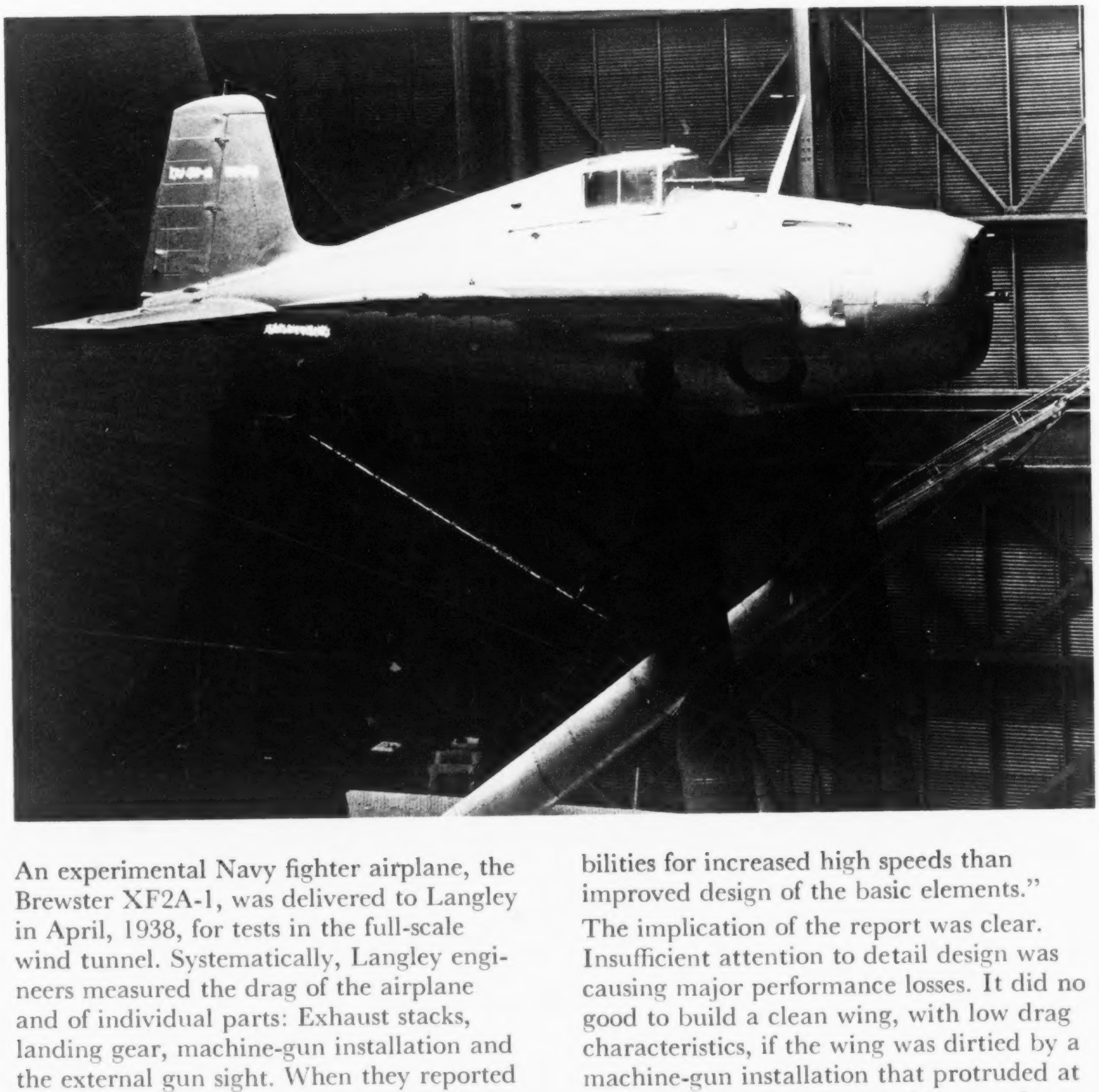
Passenger service across the Atlantic had begun in 1939 by Pan American. A little more than seven years later, the British De Havilland Aircraft Co. received an order to build two prototypes of a four-jet passenger-carrying aircraft which would become the Comet, the world's first jet transport to enter scheduled service.

The first of the research aircraft, Bell's rocket-propelled X-1, had been conceived and designed during the war. It made its first powered flight in December, 1946, and in October, 1947, Air Force Capt. Charles E. Yeager flew it through the speed of sound for the first time and pioneered the way into the age of supersonic flight.

The month before, a serious research report issued by the Rand Corporation stated that man-made satellites of the earth were completely feasible. Others had said essentially the same thing before, but they had been regarded as visionaries at best, and as crackpots at worst. The Rand Corporation was operating under funds allocated by the U. S. government, and had made the study specifically for the new Department of Defense.

The pronouncement had to be taken seriously, and it was, after the initial speculation by enthusiasts who saw supermarkets in the sky, giant lenses to burn the enemy, launching sites for atomic bombs, and a host of horrible possibilities in what was essentially a simple statement that certain technology now appeared to be available.

The earth satellite was not to be for this decade, but the Rand report was a benchmark in man's measured tread to the stars. Now there was hope that the technology of war could be turned to the peaceful development of space.



Grumman XF4F-3 prototype was tested in the Langley full-scale tunnel late in 1939; production models, modified by Langley tests, were F4F-4 "Wildcats", fighter mainstay of the U. S. Navy early in World War 2.

An experimental Navy fighter airplane, the Brewster XF2A-1, was delivered to Langley in April, 1938, for tests in the full-scale wind tunnel. Systematically, Langley engineers measured the drag of the airplane and of individual parts: Exhaust stacks, landing gear, machine-gun installation and the external gun sight. When they reported the results of the tests, they concluded that the top speed of the airplane could be increased by 31 mph., more than a ten percent improvement in performance.

This landmark test was the first in a long series of clean-up programs performed for the Army Air Corps and the Navy Bureau of Aeronautics. The success of the test program established the technique as standard for both the Army and Navy, and produced useful design data applied to future airplane projects.

By October 1940, 11 different airplanes had been tested in the full-scale tunnel, in a clean-up program of unprecedented proportion. A summary of the tests was published that month as an NACA Advanced Confidential Report, to be circulated only to industry and the military. The conclusion stated that ". . . the drag of many of the airplanes was decreased 30 to 40 percent by removal or refairing of inefficiently designed components. In one case the drag was halved by this process. Emphasis on correct detail design appears at present to provide greater immediate possibilities for increased high speeds than improved design of the basic elements."

The implication of the report was clear. Insufficient attention to detail design was causing major performance losses. It did no good to build a clean wing, with low drag characteristics, if the wing was dirtied by a machine-gun installation that protruded at a critical juncture. The machine-gun installation was necessary; but so was maximum performance of the airplane. As a by-product of these tests, designers began to realize that airplane design had to be a compromise between the theoretical ideals of the aerodynamicist's dream and the practical values of operational requirements.

As the clean-up program grew, so did other programs at Langley. The pressure was on, higher than ever, and in 1938 the Annual Report again cited the need for additional facilities. Structural research, the Committee warned in a letter to the Congress, produced the greatest single need for new additional equipment because of increases in size and speed of aircraft. Further, said the Committee, the interests of safety and of progress in aeronautics demanded that the structures facilities be added at the earliest possible date.

In October, 1938, a Special Committee of NACA was appointed to study the need for facilities and to make recommendations. The Committee's December report urged the immediate establishment of another research laboratory at Sunnyvale, California, plus the augmentation of the Langley facilities by a structures research laboratory and a stability wind tunnel.

Congress finally authorized the Sunnyvale station in August, 1939, just days before war broke out. With Europe starting to burn, ground was broken for the new laboratory at Moffett Field, Sunnyvale.

A second Special Committee, headed by Charles A. Lindbergh, was appointed following the outbreak of war, and within a few weeks turned in a report strongly recommending a third research center for powerplant work. The report said that there was a serious lack of engine research facilities in the United States. "At the present time, American facilities for research on aircraft powerplants are inadequate and cannot be compared with the facilities for research in other fields of aviation."

By mid-1940, Congress had authorized a new powerplant research facility. Earlier in 1939, money had been requested for an extension of the facilities at Langley as part of a supplemental budgetary request which included funds for the Sunnyvale lab. In November, Langley was authorized to take over additional acreage at Langley Field as the site for a new 16-foot high-speed wind tunnel, the stability tunnel, the structures laboratory, and supporting facilities.

The structures laboratory was completed in October, 1940, and the stability wind tunnel in January, 1942, along with a second towing tank for seaplane development, and an impact basin where hull loads could be measured during simulated water landings.

During 1941, both the low-turbulence pressure tunnel and the 16-foot high-speed tunnel became operational in wartime expansion. Langley capabilities had to increase at the same time that it was losing staff members to help organize and operate the new station at Sunnyvale, now named the Ames Research Center after Joseph S. Ames, NACA Chairman for 20 years.

With this exodus hardly out of the way, a second began. Congress had authorized the construction of the engine research laboratory in mid-1940, at a site near the Cleveland, Ohio, municipal airport. The new laboratory was to be geared solely to the problems of power generation and propulsion, from the fundamental physics of combustion to the flight-testing, in instrumented aircraft, of complete powerplant installations.

Personnel for the new center at Cleveland also were drawn from Langley laboratory staffs. Some idea of the magnitude of the staffing problem can be gained by comparing employment figures at Langley before and at the end of the war. In 1939, before the expansion moves, Langley had 524 people on its rolls, of which 204 were professional people. At the end of the war, more than 3,200 were employed at Langley.

During this third decade, the primary job at Langley was to refine the basic airplane that its earlier researches had made possible. The propeller-driven, all-metal airplane with a low wing, cowled engines, retractable landing gear, and flaps needed refinement. Engine power was on the rise, and corresponding improvements in airplane performance were possible. But the airplane had to be designed carefully, especially in detail, if maximum advantage was to be gained.

The drag tests on the Brewster XF2A-1 pointed the way. At first in routine programs, and later under the pressures of wartime demands, airplane after airplane went through the Langley tunnels, through the flight research department laboratory, into the spin tunnel, in model and full-size form, until all that could be known about the airplane was measured and reported.

At one time in July 1944, 78 different models of airplanes were being investigated by NACA, most of them at Langley.

Spin tests were made in the Langley free-spinning tunnel on 120 different airplane models. The atmospheric wind tunnel crews tested 36 Army and Navy aircraft in detailed studies of stability, control, and performance.

From these tests came a wealth of data, first for the correction of existing problems, and second for the designers' handbooks.

These tests were backed by theoretical investigations and experimental programs that developed airplane components to the highest degree attainable at the time. As one example, in June 1938, Langley's low-turbulence tunnel began tests of an airfoil whose contours differed from earlier designs. The point of maximum thickness was farther aft, and the trailing portion of the airfoil showed an odd reflexed form. The measured drag was about half of the lowest ever recorded for an airfoil of the same percentage thickness, and the investigation became the starting point of Langley's development of a series of low-drag airfoils.

Less than two years later, the British were to give North American Aviation 120 days to come up with a fighter prototype that met their requirements. The fighter became the famed P-51 "Mustang", after considerable development. It was one of the first fighters to use an NACA low-drag airfoil, developed at Langley as part of the overall family of laminar-flow airfoils.

Flight research work on a variety of airplanes began to build a backlog of correlated experiences on the flying and handling qualities of airplanes. Early pioneering work at Langley had given pilots a new appreciation of flying qualities, and the wartime tests sharpened that appreciation.

As performances increased, so did some of the flight problems. Again using the systematic approach, Langley pilots and engineers developed measurable handling and flying qualities for aircraft, and further defined them in terms of wind-tunnel measurements.

After 19 airplanes had been systematically tested in flight, Langley engineers prepared a summary report on the group. The report included suggestions for minimum criteria to define a "good" aircraft from the viewpoint of its handling characteristics.

That report became the foundation of the extensive work to be done later by NACA, the military services and industry. Also, it was a spur to the writing of a military specification on handling qualities, the first such to be written in this country.

Other work at Langley during the wartime period included an extensive study of wing planform shapes and their effects on the stalling characteristics of an airplane. Variations in taper and thickness ratio, sweepback and twist, were investigated in wind tunnels.

Aircraft loads in maneuvering flight, still somewhat of a mystery, were studied in flight, in the wind tunnels, and by theory.

Changes in stability and control due to engine power, another misunderstood flight phenomenon, were delineated in flight test and in the Langley tunnels.

The NACA cowling was refined further for a higher speed range. A special flush-riveting technique was developed to reduce the parasite drag of airplanes.

One pursuit plane was plagued by a series of in-flight tail failures. Langley engineers isolated the problem, helped suggest a solution. The plane went on to be one of the fondly remembered fighters of World War 2.

Another Army pursuit developed a "tuck", a tendency to steepen its dive until it "tucked" past the vertical into a partially inverted attitude, and trouble began. Wind tunnel tests at Langley in the eight-foot high-speed tunnel, and by the manufacturer, unearthed the problem. Langley suggested the dive-recovery flap, based partly on that experience and partly on some earlier test work authorized to develop a dive brake for airplanes.

Over-the-water combat flights, and the numbers of crews lost in ditching on the water, quickened interest in a way of getting an airplane safely onto the water's surface. Langley's hydrodynamics test facilities were turned to a high-priority program of testing scale models in simulated water landings and recording their behavior in motion pictures.

Some of the aircraft couldn't have been more poorly designed for landings on water. Belly intakes, bomb-bay doors, or wheel wells scooped up water and served to somersault the airplane. They sank, inverted.

The answer was to develop some kind of a ditching flap that would counter the effect of the scoops and bays and wells. Langley work produced such a flap, but it was never used on any aircraft. The production changes were regarded as too extensive.

An experimental model of an Army pursuit plane had weak ailerons, a design defect that could prove dangerous in combat maneuvering. Langley pilots flew the plane, measured its performance; on the ground, engineers pondered the problems and suggested a dual approach. First, they doubled the deflection angles of the aileron, which increased its effectiveness. Then they balanced the ailerons aerodynamically, so that the response was light and quick.

The result was an airplane with doubled roll performance, and one that set new standards by which later fighters were judged.

These were typical problems faced at Langley during the war years. It was the urgency of war that predetermined the direction of so many of the NACA programs. Most of them were aimed at the "quick fix" that would get an airplane out of its current troubles.

But most of the air war was fought with airplanes that had been designed before or early in the war, and many of these had drawn on basic NACA data for their designs. Secretary of the Navy Frank Knox said in 1943: "The Navy's famous fighters —the Corsair, Wildcat and Hellcat—are possible only because they are based on fundamentals developed by the NACA. All of them use NACA wing sections, NACA cooling methods, NACA high-lift devices. The great sea victories that have broken Japan's expanding grip in the Pacific would not have been possible without the contributions of the NACA."

As the war progressed, speeds kept edging up. The pursuit airplanes that experienced compressibility troubles emphasized the need for understanding this new characteristic of high-speed flight. It was one thing to fix a problem of high-speed flight temporarily; it could be done empirically, through tests in the Langley tunnels, or by carefully controlled and instrumented test flights.

But to avoid this problem from the start meant that the designers had to have a backlog of information, the very kind of data that NACA and the industry had been too pre-occupied to collect during the war years.

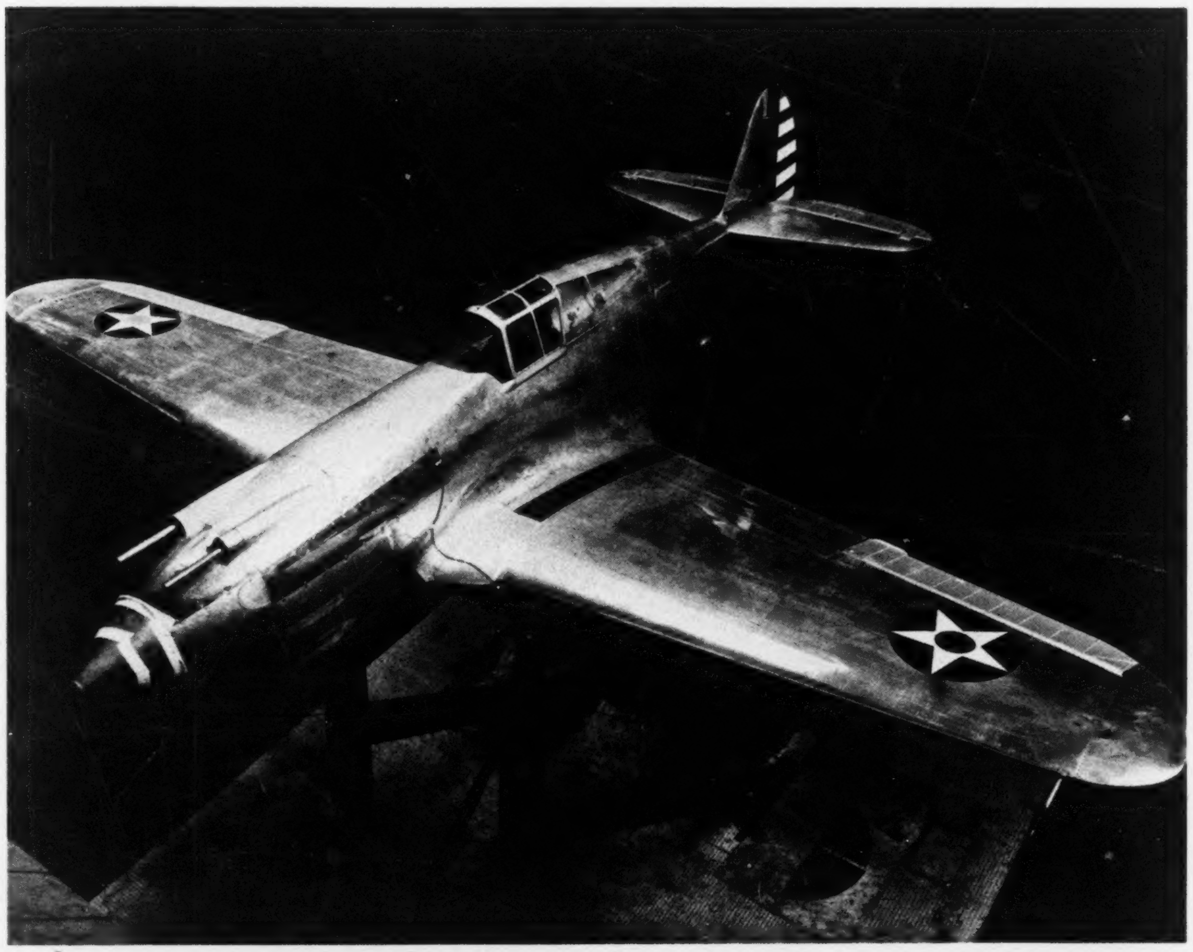
In spite of the wartime work load, Langley staff members had been thinking about some of the problems of high-speed flight. In 1939, for example, the Airflow Research staff had another look at the basic concepts of jet propulsion, a long-known principle that had briefly come to light in a 1923 Technical Report published by NACA. In this respect, NACA scientists were not alone. In other countries, their counterparts were looking at and working on the problems of jet propulsion. The Germans were close to flying an experimental jet-propelled airplane. The British had written a specification for their first. The Italians were flying a rudimentary jet-propulsion scheme in a test-bed aircraft.

But jet propulsion, in 1939, seemed like the answer only to the interception problem. That was not the major concern of the U. S. military services, who were struggling to get every bit of range out of their aircraft for strategic reasons. Back into the files went the jet propulsion reports.

Another example of high-speed research was started in 1941, when a group began to test in the eight-foot high-speed tunnel, working on propeller designs that could be used to drive an airplane at the then-unheard-of speed of 500 mph. Langley personnel in this group were the nucleus of later work on high-speed flow that was to win the agency two more Collier Trophies.

Working in the high-speed wind tunnel was a guaranteed way to unearth the problems of attaining high speeds. But it was only one of the methods that NACA traditionally had used to obtain design data. Flight tests had to supplement the wind tunnel, and a variety of other kinds of tests in special facilities, such as the free-flight tunnel, had to be integrated into a test program before the engineers believed the data was good enough to provide a design base.

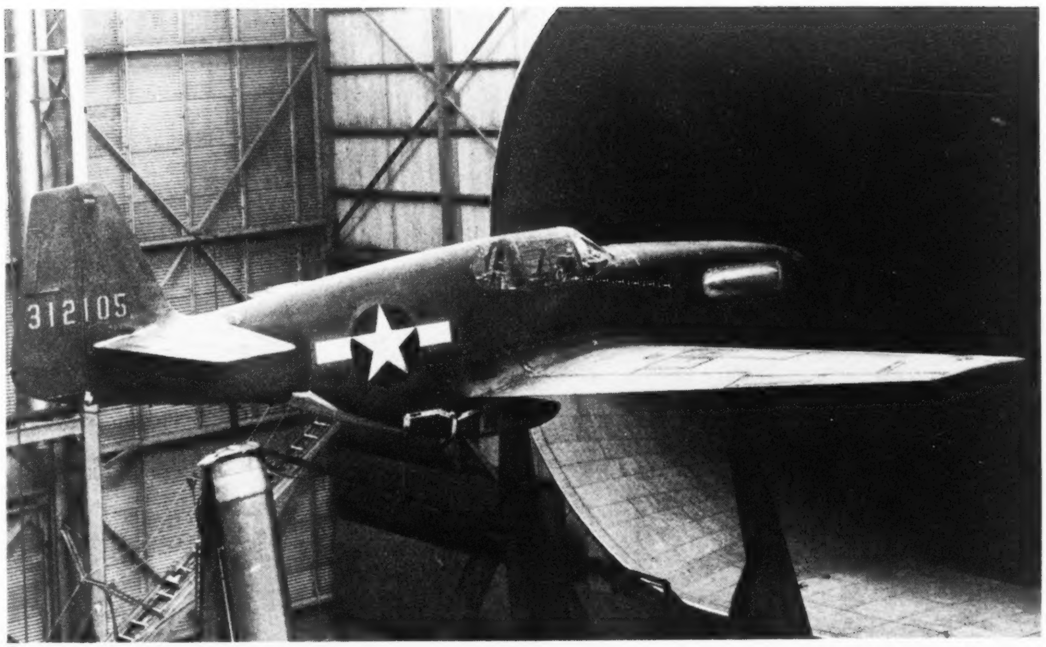
At 500 mph., designers would be working near the fringe of the transonic region and the speed of sound. That speed had been defined as a problem some years before, when a British scientist had said that sonic



Early Curtiss P-40 fighter in drag clean-up tests at Langley during 1940.

1. North American P-51B, one of the most effective air weapons of World War 2, went through drag clean-up tests in the Langley full-scale tunnel late in 1943.

2. Bell YP-59A under test in the Langley full-scale tunnel. Plane was service test modification of XP-59, first United States jet-propelled airplane, which first flew October 1, 1942.



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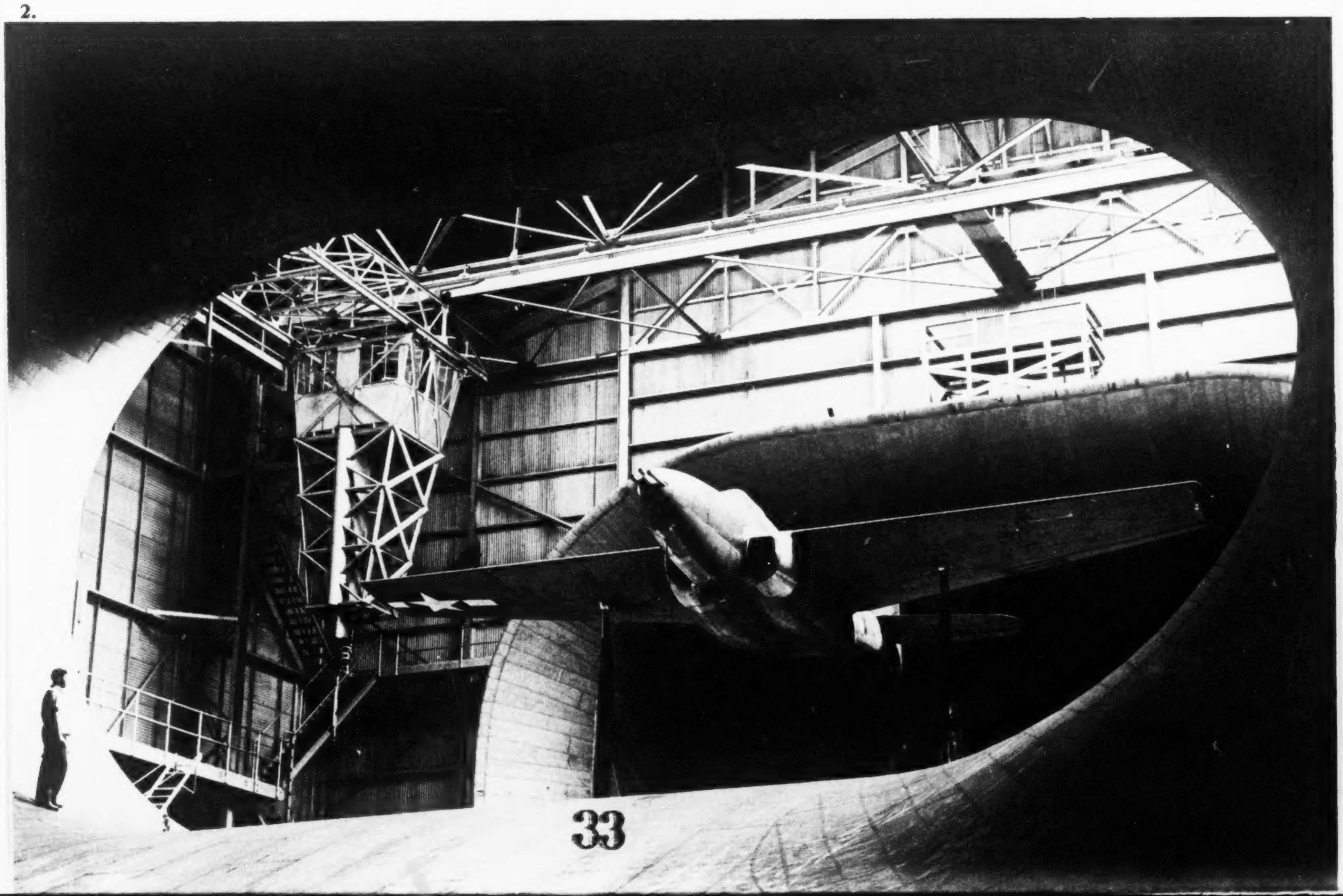


speed ". . . looms like a barrier . . ." against the further development of flight. The words, "sonic barrier", passed quickly into the literature and folklore of flight.

Was it a barrier, or only a smokescreen? There was no available way to find out.

Some flow experiments had been made at Langley by dropping instrumented and highly streamlined shapes from high altitudes, measuring forces and speeds and correlating the two to determine the change in drag and lift at the transonic region. But these results were not too conclusive.

There was one acknowledged way to get accurate transonic design data, and that was from flight tests of a full-scale airplane, built specifically to fly into and through the transonic region.

In 1943, such an airplane was conceived at Langley. More or less simultaneously, others in industry and the military labs had been thinking along the same lines.

The Langley study expanded and, in March 1944, was presented at a seminar attended by personnel from the Army Air Force, the Navy and NACA. NACA put its weight behind the study, and proposed that a jet-propelled airplane be built specifically for the purpose of flight research in the transonic region.

This was a pioneering step in aviation history. It marked the beginning of a systematic exploration of the transonic region in flight tests that would win world-wide respect and reknown. It led also to the later stable of research aircraft operated by NACA and the military in unique programs that supplied fundamental design data for years to come.

Today, research aircraft like the X-15 are being flown near the borders of the unknown, in tests which are producing design data for the aircraft of tomorrow.

This first research airplane was designated XS-1, and was to be built by Bell Aircraft Corp., where much of the original design thinking had taken form in 1943. The contract was let by the Air Materiel Command early in 1945, and design and construction proceeded.

At Langley, scientists were still trying other methods. It was not so much a case of hedging bets as it was trying to develop test techniques that would supplement those of full-scale flight, and which might indicate a way to go that was cheaper than constructing a complete airplane each time.

One of the unique approaches to obtaining high-speed flow was conceived at Langley in mid-1944. It was based on the existence of transonic flow in a small region over the upper surface of the wing of a high-speed subsonic airplane. A small, half-span model of a wing shape was built and mounted, perpendicular to the upper surface of the wing and aligned with the airflow, near the point of maximum thickness. The airplane was flown into a high-speed dive, and transonic flow developed over the wing. Instrumentation in the mount of the model wing recorded the forces and airflow angles for reduction into design data after the flight.

Revisions in instrumentation, and specifically the development of radio telemetering techniques at Langley in 1944, prompted a second series of bomb-drop tests. With an installed telemetering package, forces could be measured in flight and transmitted to a ground station for recording and future data reduction.

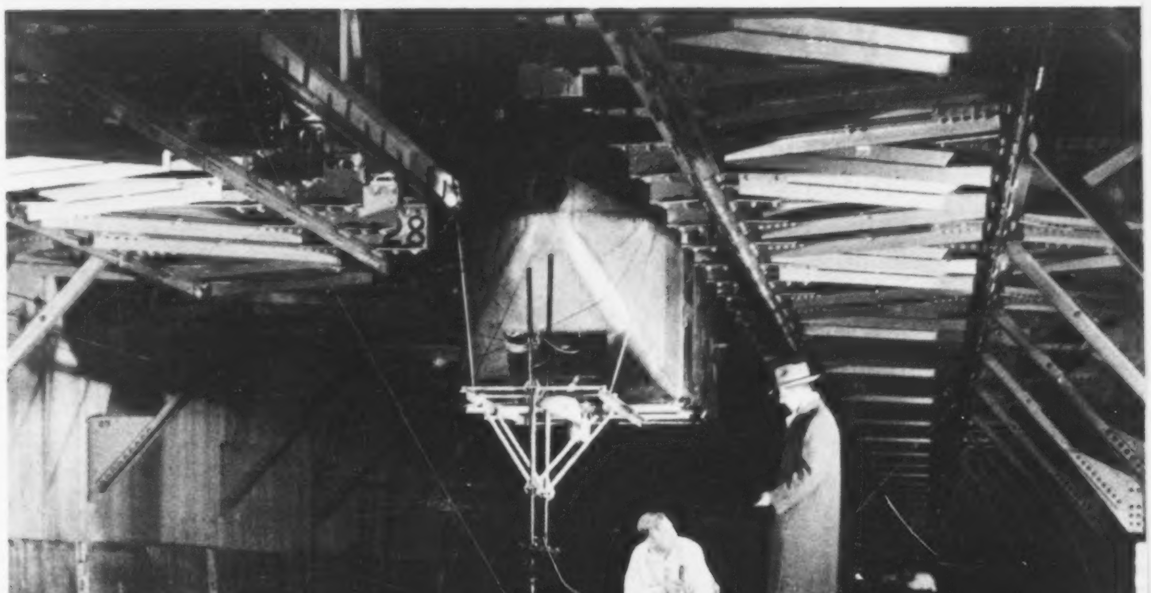
The problem was basically that the available operational altitudes didn't permit enough velocity buildup before impact of the bombs. Consequently, the data points never got very much over the sonic mark, and didn't prove too useful.

Of these techniques, the most productive results were to come from the wing-flow method tests. They determined that a thin wing didn't behave at all like a thick wing, and that its characteristics were far superior for high-speed flight.

Near the close of World War II, a Langley scientist conceived the idea of wing sweepback as one method of obtaining higher flight speeds. In effect, sweepback fools the air into thinking that it is flowing over a very thin wing, and it delays the sudden drag rise associated with the transonic region. In the supersonic speed range, a sweptback wing can be designed so that it lies entirely within the shock wave cone. This avoids the problems of mixed flow that would otherwise occur.

Wing sweepback was not a Langley invention, because other scientists were working on the idea at about the same time. The first intelligence reports that filtered back to industry and the NACA laboratories in the closing months of the war showed that the Germans had taken aggressive advantage of the concepts of sweepback, in designs of jet-propelled aircraft that—on paper—were superior to anything under development either in this country or in Great Britain.

Those designs set the pattern for the post-war years of aviation development. The demand was for more speed, higher altitudes of operation, more thrust from turbojet and rocket engines. But the XS-1 had yet to



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fly. Operational German aircraft with advanced features were so few, and the really advanced types so experimental, that there was no way of obtaining much solid data from flight tests of full-scale airplanes.

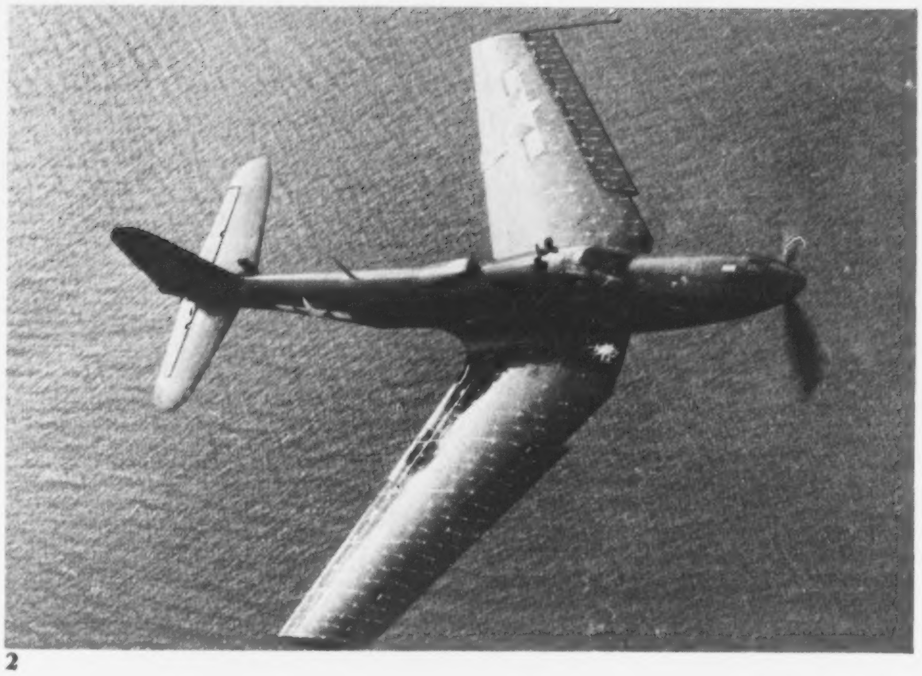
Langley had done some experimentation with rocket-propelled models, launching them from the ground in attempts to get meaningful free-flight data. This looked like a valid test technique, and the work expanded to a point where a separate test facility was established at Wallops Island, Virginia, up the Atlantic coast from Langley. The Pilotless Aircraft Research Division (PARD) moved into the area late in June, 1945, and on October 18 launched its first successful drag research vehicle.

This was a rocket-propelled model aircraft, designed to evaluate wing and fuselage shapes to provide basic design information at transonic and supersonic speeds.

The test vehicles became more elaborate. The following June, PARD launched a control-surface research vehicle which evaluated controllability in roll by deflecting the ailerons in a programmed maneuver.

Wallops Station has long outgrown that original test site and now is sprawled over portions of the former Naval air station at Chincoteague. In recent years, Wallops work has provided major contributions to the Mercury, Gemini and Apollo manned space flight programs, in tests of escape systems and other rocket-launched vehicles.

The first flight of the XS-1 was approaching, and the test work flights were scheduled to take place at the Army Air Force flight test area on Muroc Dry Lake, Calif. Program personnel were moving to the area for support of the tests, and Langley transferred 13 engineers, instrument specialists and technical observers to Muroc. The unit was designated the NACA Muroc Flight



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1. Boeing B-29 long-range bomber model was tested for ditching characteristics in the Langley tank No. 2 early in 1946.

2. Navy swept-wing modification of Bell P-63 was tested by Langley late in 1947 to determine low-speed stability and stalling characteristics.

Test Unit; it was the origin of today's NASA Flight Research Center at Edwards AFB, which grew out of the site of the Muroc operations.

The Bell XS-1 was a conservative design. Its rugged structure was planned to take a maximum load of 18 times its normal flight loads, where most fighters were designed for only nine times the normal load. Its powerplant was a proven unit. The design principles were simply stated: Avoid all identifiable uncertainties.

One of the uncertainties was the way to feed the fuel to the rocket engines. The lightest weight unit would have been a turbine-driven fuel pump, but it wasn't ready when the XS-1 needed it. The decision was made to go with a pressurized fuel system, in which bottled nitrogen gas, stored in 12 spherical containers at 2,000 psi., was used to force the fuel and oxidizer from their tanks to the engine.

The pressurized system was heavier, and displaced precious fuel so that only enough was left for two and one-half minutes of powered flight. To make the most of the available fuel supply, Bell suggested that the XS-1 be carried aloft under a specially modified Boeing B-29 bomber, and air-dropped for launch.

This would accomplish a couple of things, they said. First, it would enable the airplane to be flown without power in a series of glide flights which would establish whether or not the basic airplane design was right, aerodynamically, at lower speeds. Second, it would conserve fuel so that it could be almost all earmarked for the dash through the transonic region, for which the airplane was built in the first place.

Glide flights were made early in 1946, over Pinecastle, Florida, and the first powered flight following air-launch was made early in December that year.

Back at Langley, work still was continuing on methods to reach the same speed range in wind tunnels, or in free-flight with models. One of the major accomplishments during 1946 was the development of a rocket-powered research vehicle that flew faster than 1,100 mph. It was part of the work done at Wallops Island, and it was launched to test a series of wing planforms of different sweepback angles and proportions.

The wing-flow method of transonic speed studies was adapted for wind-tunnel use by installing a hump in the test section of the seven- by ten-foot wind tunnel at Langley. Mach numbers of about 1.2 times the speed of sound could be reached before the tunnel "choked" with the shock waves of supersonic flight and the results became uncertain.

It was, and is, the presence of shock waves in the tunnel test section that makes it so difficult to obtain meaningful results around the speed of sound. But Langley researchers postulated that the shock waves could be cancelled or absorbed instead of being reflected. If absorbed, then the test section would be free of the reflected shocks that disturb the flow and the measurements.

Two Langley researchers, one working with flow theory and the other with experiments in a small 15-inch tunnel attached to the 16-ft. high-speed tunnel, were able to establish transonic flow in a test section which had been slotted with longitudinal openings. The slotted throat absorbed the shock waves and kept the test section clear for measurements.

This was a breakthrough in wind-tunnel technique. It led directly to the development of the slotted-throat tunnel for transonic flow studies, and later, in 1951 after the story could be told, won a Collier Trophy for John Stack and his associates at Langley.

In April 1947, PARD (Pilotless Aircraft Research Division) launched its first scaled-down airplane in a test for performance evaluation. It was a model of the Republic XF-91, a radical fighter design which combined turbojet and rocket engines for performance at extreme altitudes.

The success of this test program was followed by model flight tests of most of the Air Force and Navy supersonic and subsonic aircraft designs.

Then, on October 14, 1947, the sonic barrier no longer was a mystery. The Bell XS-1, piloted by Air Force Capt. Charles E. Yeager, reached Mach 1.06 on its ninth powered flight, in a clear demonstration of controllable flight through the transonic region.

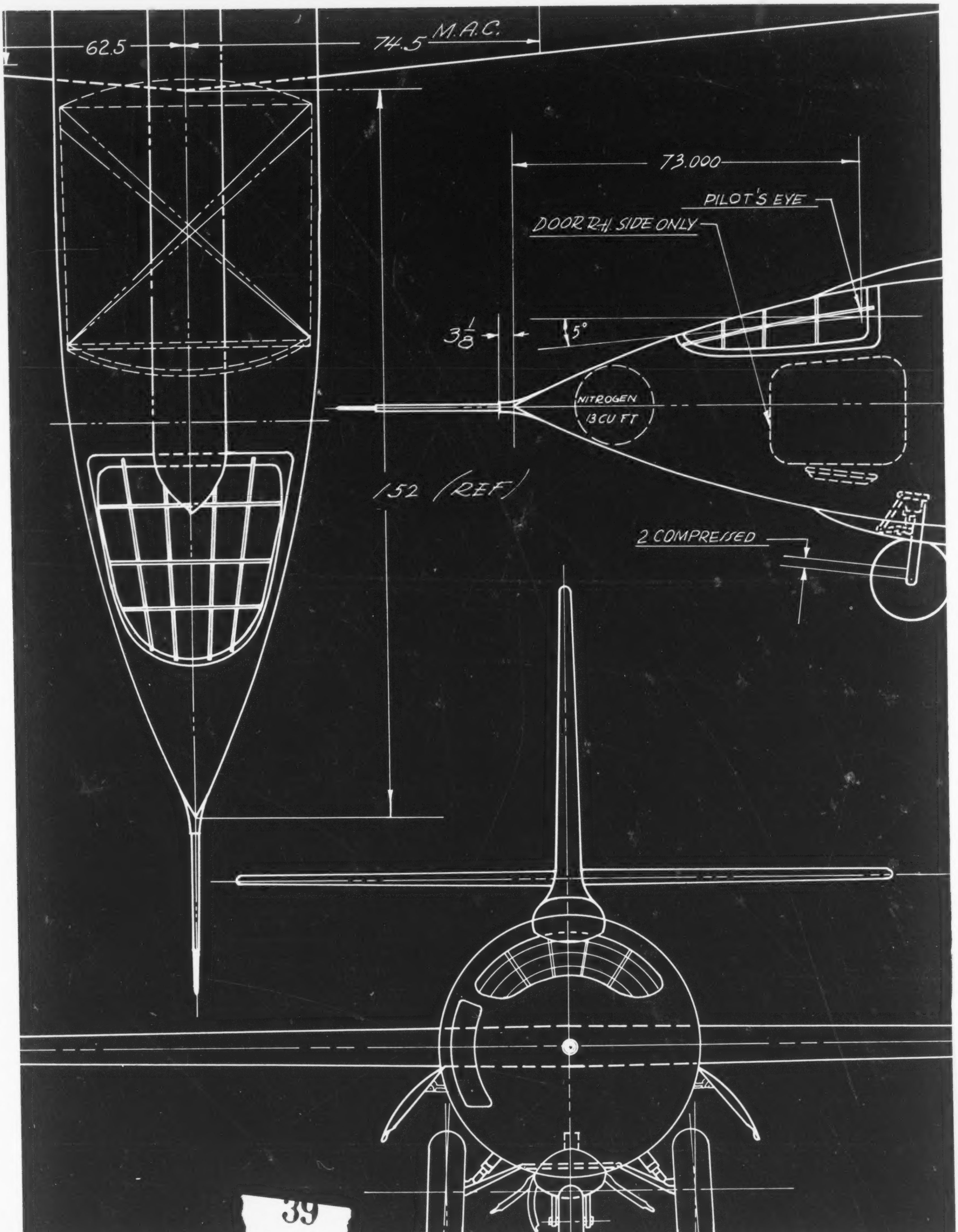
It was the first of many supersonic flights to come for the XS-1 (later to be designated the X-1 and to be joined by sister ships in the same series with improved performance) and, later, for other experimental and production aircraft.

But it was the pioneering achievement of the XS-1 program and the people associated with it that was recognized by the award of the Collier Trophy for 1947 to Langley's John Stack, Lawrence D. Bell of Bell Aircraft, and Capt. Charles E. Yeager of the United States Air Force.

Supersonic flight now is no longer unique. Within a few years, airline passengers will be traveling at speeds nearly three times that reached during the first piercing of the sonic range.

But in 1947, the attainment of supersonic speed was a history-making culmination of a long research effort that had begun early in the war at Langley Memorial Aeronautical Laboratory (now, Langley Research Center). It was also the first step into the future of a new and pioneering age in aviation—the age of supersonic flight.

Sixteen aircraft are waiting for flight tests at Langley during a typical day in World War II.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1948-1957

The fourth decade of research at Langley was characterized by rapid and drastic changes in aircraft types and performance, often shaped by the application of new technologies drawn from NACA experience.

In the ten years between 1948 and 1957, the speed of service fighters in the U. S. Air Force and Navy virtually doubled. In September 1948, the world speed record was raised to 670.981 mph. by a standard North American F-86A fighter. At the end of the decade, a McDonnell F-101A "Voodoo" blasted its way to 1,207.6 mph, beating by a handsome margin the previous record set by a British research aircraft, the Fairey Delta 2.

Transportation speeds increased also. In 1948, the British flew the world's first turboprop airliner, the Vickers Viscount, and followed it with the first flight, in the following year, of the De Havilland Comet, a turbojet-propelled transport.

The Comet entered scheduled airline service with British Overseas Airways Corp. in May, 1952. Two years later, the bright dreams were dulled by tragedy and the Comet was withdrawn from service.

The remarkable series of "X" aircraft, which had been born during the previous decade with the Bell XS-1, grew into a stable of diverse types to probe and analyze new problem areas. From the barely supersonic performance of the original X-1, the research series blasted first past Mach 2 and then Mach 3 speeds.

The first tentative steps toward vertical takeoff and landing (VTOL) aircraft were taken, and development later was spurred partly by the outstanding success of the helicopter in the Korean action, and a knowledge of its shortcomings.

The "Century Series" of fighters, so-called because of their numerical designations which started with F-100, were developed and flown during this decade, and set new performance standards. They also posed new stability and control problems, such as roll coupling and pitch-up, which were to plague their designers and NACA for solutions.

And finally, in the closing months of the decade, North American Aviation was awarded the contract for the XB-70 bomber, an awesome aircraft intended to fly at three times the speed of sound.

The airplane had come fast and far in the decade between 1948 and 1957. The Berlin Airlift, which began in June 1948, was flown with the piston-engined transports left over from World War 2, and designed before then.

The Consolidated Vultee B-36 was the standard bomber of the Air Force, and jet-propelled fighters were just getting to squadrons. There was a change in the offing, marked by the first flight of Boeing's XB-47, a six-jet sweptwing bomber, which took to the air for the first time February 8, 1949.

But the U. S. went to war in Korea with left-over Boeing B-29 bombers, and the first kill was made by a North American F-82 Twin Mustang, a piston-engined fighter.

In November 1950, the first dogfight between jet aircraft seared the sky over Korea and set the pattern for future combat.

In June 1951, the Bell X-5 flew for the first time. One of the research aircraft, it was characterized by its ability to change the sweep angle of its wing in flight. It was the precursor of the General Dynamics F-111A fighter and the Boeing supersonic transport.

Air transportation made a tremendous impact on the public during the Berlin Airlift. Three years later, air passenger miles overtook Pullman passenger miles traveled for the first time. The trend has never reversed.

The Boeing 707 prototype, first of a long line of jet transports, made its first flight July 15, 1954. Later, the French made a unique contribution with the Sud Aviation Caravelle, whose rear-mounted turbojets set a style trend. The Caravelle first flew May 27, 1955.

In October that year, Pan American World Airways ordered 45 jet transports, 25 DC-8s from Douglas and 20 Boeing 707s. The first round of jet orders was sparked by this move, and the jet race was on.

In January 1951, the Atlas intercontinental ballistic missile program was started. It was to draw heavily on aviation's scientific, engineering and organizational talents. But more than that; it was to become the tail that wagged the dog. From a small start, the Atlas and its descendants grew to dominate the aircraft industry, its educational system, its management techniques, its personnel moves and its funds. It even changed the name of the industry to "aerospace."

Before the decade ended, the unexpected happened. On October 4, 1957, a rebroadcast "beep-beep-beep" signalled that the first man-made satellite of the earth was in orbit, and that it was Russian. Sputnik's signal had a mocking sound to frustrated U. S. engineers.

The insult was repeated less than one month later by Sputnik II and a passenger—the dog, Laika.

Sputniks I and II triggered a chain reaction that is still mushrooming today. They affected Langley in a way that re-oriented its thinking, re-allocated its money, and redirected its efforts. And it forced the birth of the National Aeronautics and Space Administration in 1958.

It was to be a long step from the first breaching of the sonic barrier to the achievement of sustained, efficient supersonic flight, and nowhere was that better understood than at Langley.

The Bell XS-1 had flown supersonically by the "brute strength" method. It had little endurance. It had to be carried aloft by a mother ship to conserve the fuel which would have normally been used for takeoff and climb. It was powered by a rocket engine with a prodigious appetite for fuel. It was a great research airplane, but it would have made a terrible operational military or civilian aircraft.

More practical designs had to be achieved and NACA mounted an attack on the problems of sustained supersonic flight along a number of salients.

The jet engine had grown up and promised enough thrust, at operational altitudes, to propel a less-radical airplane than the XS-1 through the speed of sound. The general concept of the swept wing indicated that drag reductions were achievable, enough to complement the available thrust and make for supersonic flight.

Some data was available on components or on generalized shapes that indicated trends but didn't solve any of the detailed design problems. The question of how to get high lift out of a thin wing had not been answered. Efficient air inlets for supersonic speeds were lacking. Control systems were still tied to subsonic data obtained earlier.

And worse, there was a realization that no longer was the airplane a simple linear design, a finished structure made up of component building blocks that had each been designed separately. The design of a supersonic airplane, and in fact, of any efficient high-speed airplane, was going to have to be an integrated whole, in which each component interacted with every other, and none could be changed without affecting the overall design, perhaps radically.

This was the general statement of the problem that faced Langley researchers as they entered their fourth decade of research work. The supersonic age was crowding in on them. Requirements for military aircraft were beginning to work into and beyond the transonic region, and new data had to be obtained fast.

Fortunately, the slotted-throat wind-tunnel technique had been developed just a couple of years before, and was beginning to promise accurate results in a region where test work had been uncertain, at best.

Wind tunnel facilities, always a strong portion of the Langley laboratory, were planned around the slotted-throat concept. A new eight-foot transonic tunnel was first approved for construction by the Research and Development Board of the Department of Defense in May, 1949. In December of that year, the original eight-foot high-speed wind tunnel, an existing Langley facility which had been converted to a slotted-throat test section, ran with sustained transonic flow for the first time.

One year later, the same trick was performed in the 16-ft. high-speed tunnel converted to a slotted throat.

This work led directly to another Collier Trophy in 1951, awarded to Langley's John Stack and his associates for their work in the conception, development and practical application of the slotted-throat for transonic wind tunnels.

Continuing work by the Pilotless Aircraft Research Station at Wallops Island paralleled the studies in the transonic tunnel and extended them into the supersonic speed range reachable with rocket-propelled models.

Slowly, the transonic region yielded to probing and analysis. The basic problems began to be defined, and the numbers that were developed in tests showed where the problems really lay.

The biggest difficulty in getting an airplane to fly supersonically was to get it through the transonic region rapidly so that it didn't have to waste precious fuel in a slow acceleration through the Mach one range. The problem was that, in the transonic region, there was a sharp increase in drag coupled with a corresponding decrease in lift. Changes in lift meant that control problems might well appear. They could be handled, if they were defined, understood and curbed. That knowledge was to come later.

For the moment, the concentration was on getting through the transonic region. How could the drag be reduced?

One of Langley's scientists, Richard T. Whitcomb, had an intuitive feeling that the drag rise was due to the interference between wing and fuselage. Some tests proved, to his satisfaction, that this was so.

Adolf Busemann, a transplanted German scientist who had contributed to highspeed aerodynamics over at least a decade, spoke in November 1951 about the "pipe flow" characteristics of the transonic flow region. What he meant was that cross-section areas of the stream tubes—those nebulous surfaces defined by a cluster of streamlines in air flow—didn't change as the flow passed through the transonic region.

Whitcomb thought about this, and between the insight from Busemann's comments and some additional tests, he derived the area rule, a basic design concept which—in the words of a Langley associate—made sustained supersonic flight possible.

The area rule, crudely stated, says that the cross-section areas of an aircraft should not alter too rapidly from the front of the plane to the back. This minimizes the flow disturbance and the transonic drag rise.

For example, the presence of a wing on a fuselage adds extra cross-section area to the airplane. To compensate for the additional wing area, some area must be removed from the fuselage. The result is an indentation on the fuselage where the wing is located. This "wasp-waisted" appearance, or "Coke-bottle" shape, is one characteristic of the early application of the area rule to transonic flight.

Tests of the concept as a design tool began in February 1952, and they were quickly applied to two military aircraft: Convair's XF-102, which showed no hope of reaching its low supersonic design speed, and the Grumman XF11F-1, which had, in the early design stages, a low supersonic speed as one of the design goals.

Both airplanes later sliced through the transonic region with little difficulty, and with no more power than before.

The work was kept under wraps at Langley, because it was a genuine breakthrough in airplane design. It was finally released publicly in 1955, when Whitcomb received the Collier Trophy for 1954 for ". . . discovery and experimental verification of the area rule, yielding higher speed and greater range with the same power."

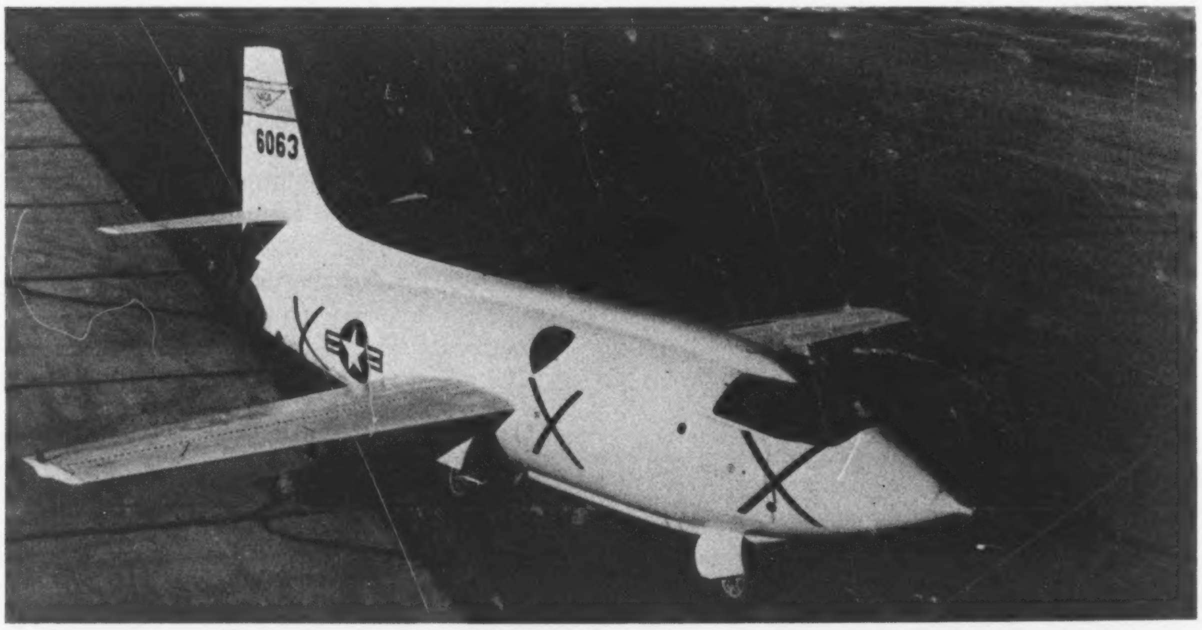
The work continued, and extensions of the transonic area rule were developed for design of supersonic cruise aircraft. General Dynamics' experience with the F-102 design had made the company a believer, and they designed their B-58 bomber using the supersonic application. It was the first airplane to be designed by the supersonic area rule concept, and it made its first flight November 11, 1956.

Part of the success of the B-58 bomber was due to a tiny delta-winged aircraft with a fighter designation: XF-92A. This had been built as a fighter airplane, and assigned later to a research program to determine whether or not the delta-winged planform was the correct approach to highspeed flight.

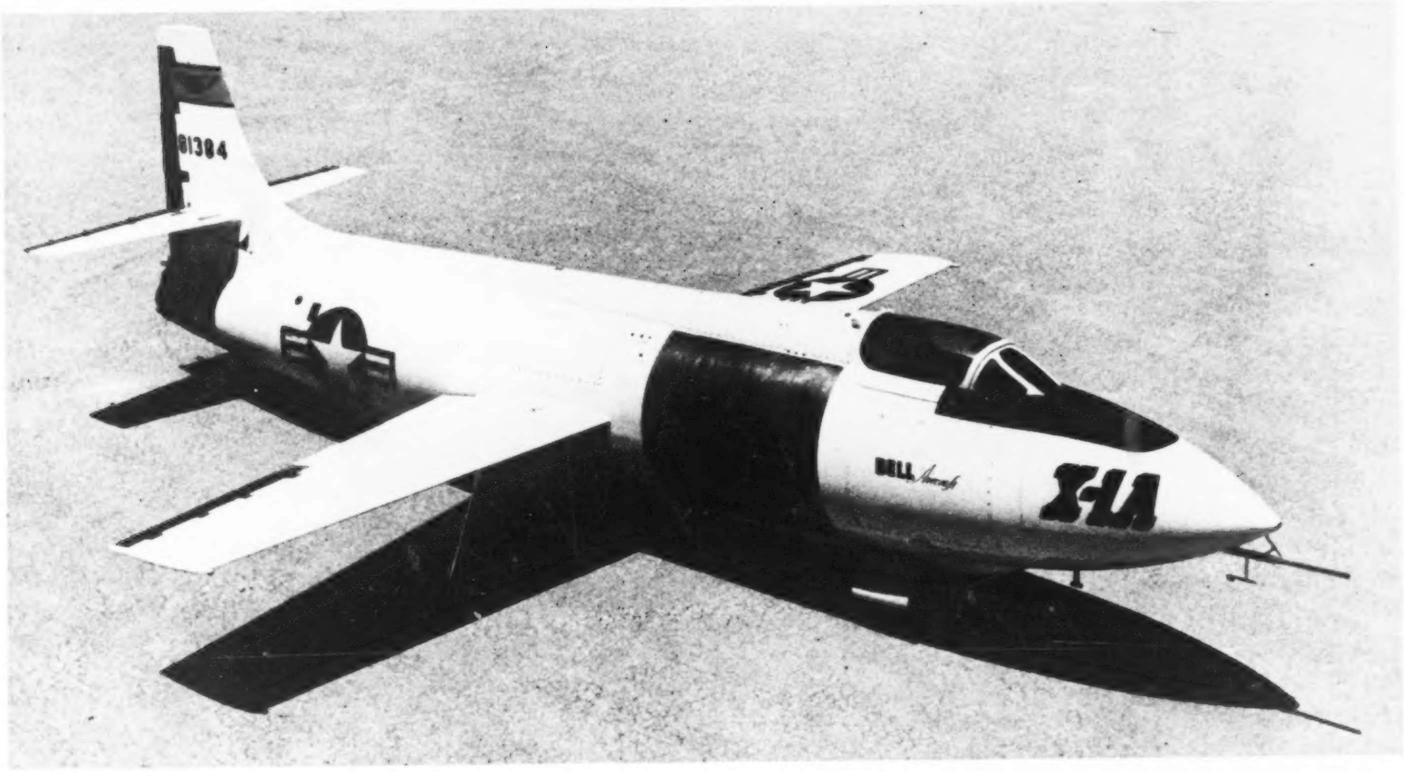
It was barely supersonic in a steep dive, according to one of the Air Force pilots who tested the XF-92A. But dive tests showed that transition through the transonic region into the low supersonic was easier with the thin delta wing than with either the thicker sweptwing F-86 or the straight-winged F-94, both of which were capable of crossing the transonic region in a dive.

The XF-92A later joined the NACA group of research airplanes, and was extensively tested in flight before its retirement.

That group of research airplanes, born during



Research aircraft pioneered flight into the supersonic range and led the way to supersonic fighters and bombers. Second Bell X-1, flown by NACA pilots from 1948, later modified to become X-1E.



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the previous decade at Langley, in the military services and industry, grew to be one of the most valuable sources of aircraft design information ever assembled.

The Bell X-1, progenitor of the series, had flown through the sonic speed range in 1947. A second research aircraft, the straight-winged Douglas D-558-I Skystreak, had begun its flight test program early in 1947, and by August that year had established a new world speed record of 650.8 mph.

A second D-558 design, the Skyrocket, was developed by Douglas Aircraft and the Navy. It featured a swept wing in addition to a rocket powerplant in combination with its turbojet. Three of the sweptwing craft were built, and one of them—rocket-propelled and air-launched—became the first aircraft to break the Mach 2 mark.

A major step forward was the Bell X-2, intended to explore the region of flight above 100,000 feet and up to speeds of Mach 3. Built of K-monel and stainless steel to solve the expected heating problems, the Bell X-2 was powered by a throttleable rocket engine. It was a short-lived program, marked by tragic losses of both airplanes and two pilots. But in its brief moment of glory, the airplane reached a peak altitude above 126,000 feet, and a speed of Mach 3.2.

But more than speed and altitude performance was in the minds of the engineers who worked with the research aircraft.

The Air Force funded a program on the Northrop-built X-4, a tailless airplane designed on the premise that elimination of the horizontal tail surface would reduce the problems associated with wing-tail combinations in the transonic region. The airplane became a reliable test vehicle, although its speed range was on the low side of the transonic region.

There was an X-3, originally conceived to explore the problems of sustained supersonic flight. Needle-nosed and with tiny, straight-tapered wings, the X-3 proved to be underpowered and overloaded. In spite of that, experienced pilots kept the airplane operational over a four-year span from 1952 to 1956, and succeeded in obtaining much data on the behavior of very thin wings in the transonic region.

Flying the X-3, which was an airplane whose inertia characteristics were different from almost all of its predecessors, uncovered a highspeed flight problem of inertial coupling. Crudely stated, the airplane wallowed in the air. If the pilot wanted to turn the airplane in a banked attitude, the unusual distribution of the airplane's mass—strung out along the fuselage, but essentially zero in a spanwise direction—resulted in a yawing motion as well. Sometimes the yaw was wild and uncontrollable; the first version of the North American F-100 supersonic fighter broke up in the air from this uncontrollable motion.

As a sidelight, the problem of inertial coupling had been studied in theory and reported by Langley in 1948. The report languished in files until trouble set in. Then it became a keystone of the flight and tunnel-test programs that were mounted on an emergency basis to solve the problem.

The fifth designated X-airplane was a different approach. It was built around the concept of a variable-sweep wing whose sweepback angle could be changed in flight. The concept was probably born, and certainly was advanced, in the Langley laboratories, although the genesis of the idea is argued today and remains controversial.

The fact is that Bell Aircraft submitted a proposal to the Air Force in July 1948 for a research airplane whose wing sweep was variable in flight. The USAF went to NACA with the suggestion that the airplane become part of the joint research aircraft program. NACA accepted, endorsed the program, and the X-5 began to take form.

How did it originate? The thought probably occurred to several people who thought about one of the main problems of the sweptwing aircraft. The layout was fine for highspeed flight, but it left much to be desired at the low-speed end. If it were possible to vary the wing sweep from zero at low speeds to the optimum angle for high speeds, the problem could be solved.

In 1945, work at Langley began in the free-flight tunnel on a skewed wing, pivoted on a vertical centerline and rotating so that one wingtip moved forward and the other aft. This curious configuration "... ex-

1. Bell X-1A, briefly on NACA roster in 1955.

2. Bell X-2, flown only by USAF pilots, was tunnel-tested at Langley.

2

hibited surprisingly good flight characteristics up to skew angles of about 40 degrees." Results were published in Technical Note 1208.

Two years later, a model of the Bell X-1 was modified for tests of variable sweep in the Langley 7- by 10-ft. tunnel. The experiments produced results that showed variable-sweep concepts to be feasible. The tests also showed that it would probably be necessary to move the wing along a fore-and-aft line in order to keep the stability characteristics within the desirable range.

Bell's background in research aircraft design, and the work done by Langley in the wind tunnels from 1945 to 1947, were combined by Bell in the proposal for the X-5.

The airplane first flew June 20, 1951. It became part of an extensive flight-test program which investigated the effects of sweep on performance and flying qualities. The sweep angle was changed in flight many times with no problems.

The earlier work at Langley was proved right, though, because the Bell X-5 was designed—fortunately—with a mechanism that moved the entire wing forward as it was swept back, in order to keep stability and control positive.

One important benefit, which remains relatively unknown today, was the knowledge gained about the response of a high-speed, highly swept airplane to gusts during fast, low-altitude flight.

The X-5 was flown near the ground with its wings swept fully back to 59 degrees, and the data obtained during those runs was to become an important consideration in the later design of variable-sweep fighters for their tactical role.

Prior to and during the X-5 test program, Langley tunnels and other facilities were used in parallel studies on models in wind tunnels, at low speeds and at high, using the transonic bump technique, and in-flight tests of semi-span models using the NACA wing-flow technique.

Meantime, the Navy and Grumman Aircraft Engineering Corp. were developing the XF10F-1, a variable sweep fighter first flown in May 1952. Langley tested models of the XF10F-1 in the transonic wind tunnel and in flight, using the rocket-propelled technique at PARD, Wallops Island.

The airplane was a failure, even though the incorporation of variable sweep contributed nothing to that failure. There were no serious mechanical problems with the moving wing, but flight and other limitations on the airplane resulted in little or no useful data on the application of variable sweep to a military aircraft.

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The variable-sweep studies continued at Langley only on an interim basis for a number of reasons. First, in the early 1950s, there was no military requirement for sustained supersonic speeds; interest was limited to a subsonic cruise to target areas with a supersonic dash over the target.

Second, there was no low-level operational requirement to minimize the chance of radar detection. The ability of a highly swept aircraft to fly low and fast, proven in some of the test flights of the X-5, was not yet to be put to the test of a military application.

But later, a military requirement—WS-110—was proposed that required a sustained supersonic cruise for a strategic bomber design. Other military mission requirements began to include a low-level penetration run at high speed. The need for short-field capabilities and ferry range in aircraft became of military concern.

All of these considerations—sustained supersonic cruise, low-level penetration at high speed, STOL capability and long ferry range—were to coalesce later in designs using some of the concepts of variable sweep pioneered at Langley. But for the remainder of the decade, work persisted at a low level of activity.

But WS-110 was beginning to create a design revolution. In late 1954 the need was advanced for a B-52 replacement with

1. In quarter-scale, the Bell X-1 is investigated in the 16-foot transonic tunnel's slotted throat in a Langley test program.

2. Dynamic models of the Bell X-5, a variable-sweep research airplane, show the different wing forms tested at Langley in the spin and free-flight tunnels.

2

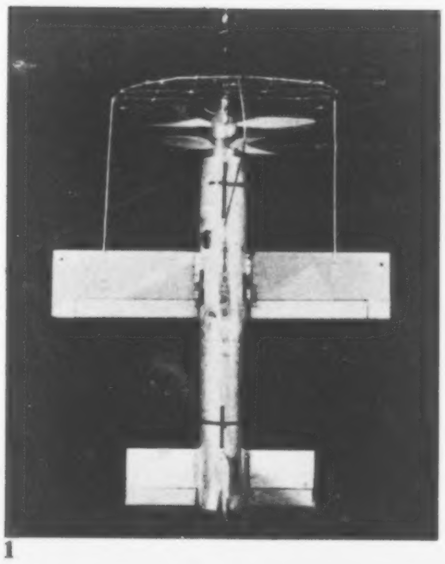
the capability to operate from existing runways and to use existing maintenance facilities. It should have a minimum unrefuelled range of at least 6,000 nautical miles, and a speed that should be as high as possible.

Supersonic flight over long distance, with the conventional airframe-engine combinations of the day, resulted in proposals for gigantic aircraft with incredible and complex layouts. The designers were sent back to the drawing boards, and WS-110 was reduced to feasibility studies.

North American's proposal for the WS-110 was finally chosen, and after much travail, became the XB-70 program with all its associated political and technical problems. It eventually lost out to the concept of a mixed missile-and-aircraft force, and to the eventual replacement of that mix entirely by missiles.

Langley scientists claim no major role in the concept of the B-70. But they emphasize that the Langley research program in support of the airplane directed their attention to the problems of sustained supersonic flight and emphasized those problems to such an extent that they have been thinking about long-range supersonic cruise aircraft ever since.

During this fruitful decade at Langley, one of the most important and significant airplane designs of all time was born: The X-15 hypersonic research aircraft. Its origin



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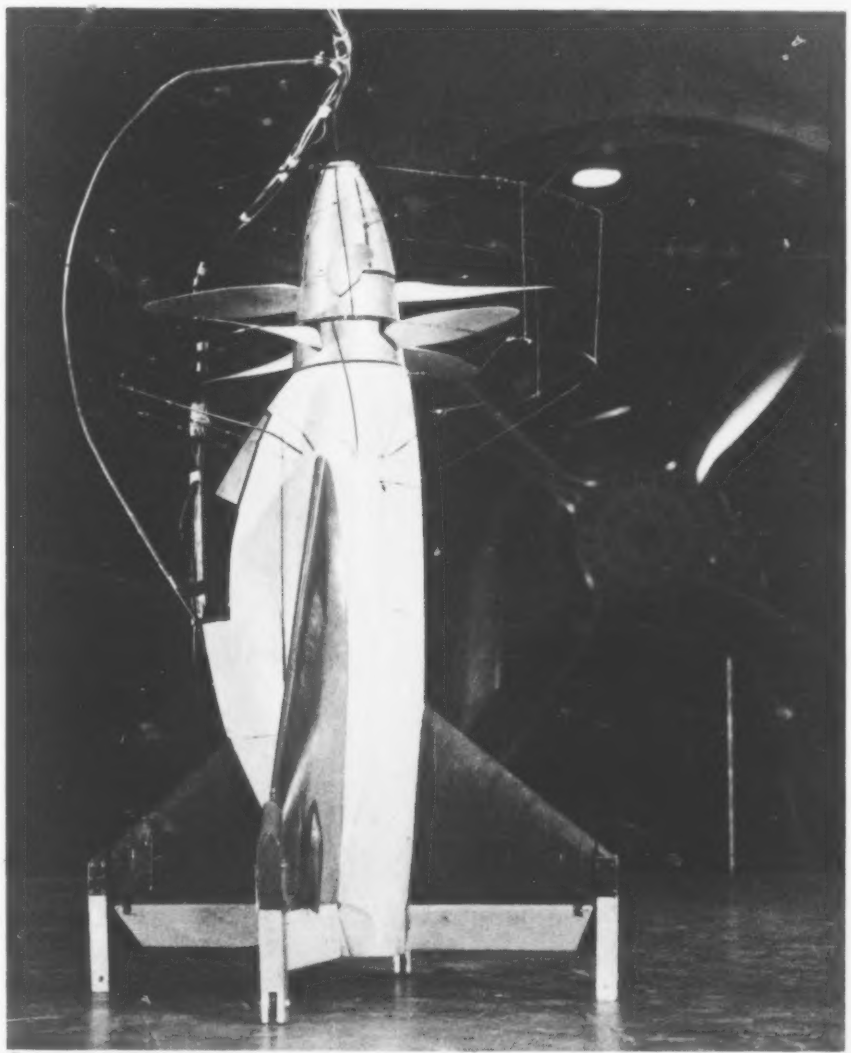
is traceable to a document of January 8, 1952, from Bell Aircraft Co., who had been associated with the design and development of the X-1, X-2 and X-5 research aircraft. The document included a proposal for a manned hypersonic research aircraft used in support of a proposed NACA group which would be formed to evaluate and analyze the basic problems of hypersonic and space flight.

In June 1952, NACA's Committee on Aerodynamics passed a resolution which recommended that NACA increase its program for the speed range between Mach 4 and Mach 10, and that it look at even higher velocities.



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1. First Langley VTOL model, this rudimentary aircraft pinpointed problem areas for subsequent test programs.

2. Convair XFY-1, tail-sitting VTOL development aircraft, was checked in free-flight model form in the 30- by 60-ft. full-scale wind tunnel at Langley.

3. Flaming halo was produced by ramjet propulsion for rotor tested on the Langley helicopter test tower.

Langley set up a study committee to evaluate the Bell suggestions and an accompanying proposal for a rocket-propelled, variable-sweep manned research aircraft. In addition, two unsolicited proposals for aircraft of similar performance had come through the NACA channels. One was for a two-stage vehicle and the other was for a major modification to the existing X-2 design.

In March 1954, NACA's interlaboratory Research Airplane Panel decided that a completely new research vehicle was the better route to travel. The problem was referred to the four NACA laboratories for detailed study of goals and requirements.

By July that year, the studies had crystallized to the point that two of them—Langley's and that of the NACA High Speed Flight Station at Edwards—could conclude that a Mach 7 research airplane was feasible and desirable.

Air Force and Navy representatives met with their counterparts at NACA that month and listened to the presentation of the proposed research airplane. Following the meeting, industry teams visited Langley to discuss the proposals in detail.

In October 1954, the Committee on Aerodynamics held a meeting which produced an endorsement of the NACA proposals. Air Force and Navy joined NACA in a joint task of defining the specification. Its requirements coincided generally with the results of the Langley study.

In December 1954, NACA made the formal presentation to the Air Technical Advisory Panel of the Department of Defense. They approved the idea, specifying that NACA should be the technical managers of the program, and that the panel itself would have the chance to review proposed designs when submitted by industry.

This was followed by a memorandum of understanding among Air Force, Navy and NACA, which established the Research Airplane Committee to direct the project technically. Initial steps toward a design competition were taken December 30 and invitations for proposals were sent to industry.

The proposals came in the following summer, and by autumn 1955 had been evaluated. North American Aviation was awarded a contract for three X-15 aircraft in June 1956; Reaction Motors division of Thiokol Chemical Corp. received the engine development and production contract.

Wind-tunnel testing and work on development of structural components began in 1956, and was able to produce enough useful data to enable construction of the airplane to begin in September 1957.

The first flight of the first X-15, in a powerless glide, was to be made in June 1959. NACA, then NASA, did not begin to fly the X-15 until after its delivery to the government in March 1960.

Programs like the X-15, the XB-70 and the development of such concepts as the area rule and variable sweep are the spectacular evidence of work done in research laboratories. But behind these tangible forms lay many man-years of effort in the painstaking development of systems and components for flight.

During the same years of these aircraft developments, NACA was laying the groundwork for the decades of supersonic flight in military and commercial airplanes that would surely follow.

Configuration studies, both generalized and specific, were made in wind tunnels, developed in theory, and evaluated by flight tests with rocket-propelled models. Families of wing planforms for highspeed flight were developed, as were control systems and high-lift devices for the thin swept surfaces. Such aerodynamic contributions to the science of highspeed flight as the low-set horizontal tail, located to avoid pitch-up problems, and inboard ailerons, which were more effective and less stressing than conventional wingtip controls, grew out of the research programs at Langley. They were applied to the Century Series of fighters, among other aircraft.

In structures, the work of the Langley laboratory found eager acceptance by the analysts of flutter and vibration problems. An accelerated effort began early in 1955 when the 19-ft. tunnel was modified to enable tests of dynamic flutter models to be made. The tunnel then could be run over a greater range of Mach numbers and Reynolds' Numbers, at an altitude range from sea level to an equivalent of 95,000 feet.

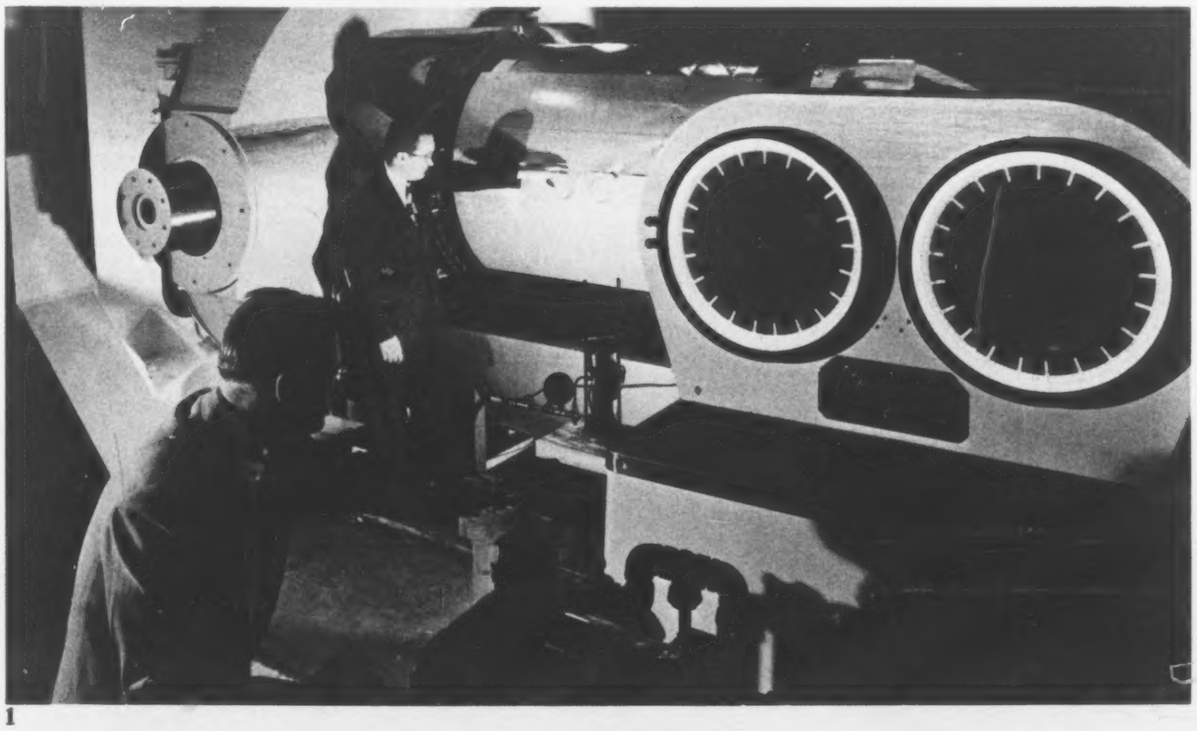
Tests like the ones conducted in the modified tunnel, coupled with theoretical analysis, enabled Langley engineers to make significant contributions to the development of techniques for predicting flutter at transonic and supersonic speeds.

Additional contributions were made in the areas of fatigue criteria and prediction of loads on structures in flight and on the ground.

Helicopter work, which had begun in pioneering effort during Langley's second decade, and was accelerated with the availability of the rotor test tower in the next decade, continued in this ten-year period. It involved flight tests of the new machines, to gain an appreciation of their handling qualities and to help define them for the benefit of future designs. Special helicopter airfoil sections were developed, extending the fundamental work done on airfoils by Langley in its early wind-tunnel work.

Helicopter stability, a tough nut to crack, was analyzed and methods were developed to predict it. The loads imposed by gusts and maneuvers were explored in flight and in test work on models and full-scale rotors.

Fundamental work in hypersonic aerodynamics pointed the way toward the X-15 research aircraft program. But it also laid a solid foundation for the coming programs in manned space flight and the future applications of hypersonic technology to commercial transport.



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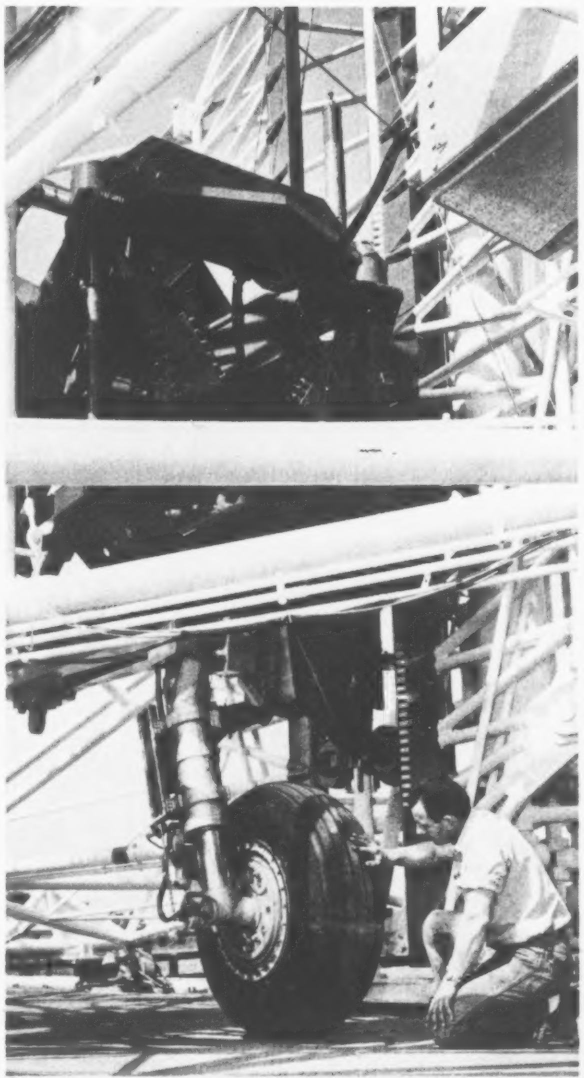

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A landing-loads track began operation during this decade, using a car propelled by a high-pressure stream of water. The car could carry typical aircraft landing gear, and subject them to the dynamic load situations encountered in aircraft landings and arrested landings.

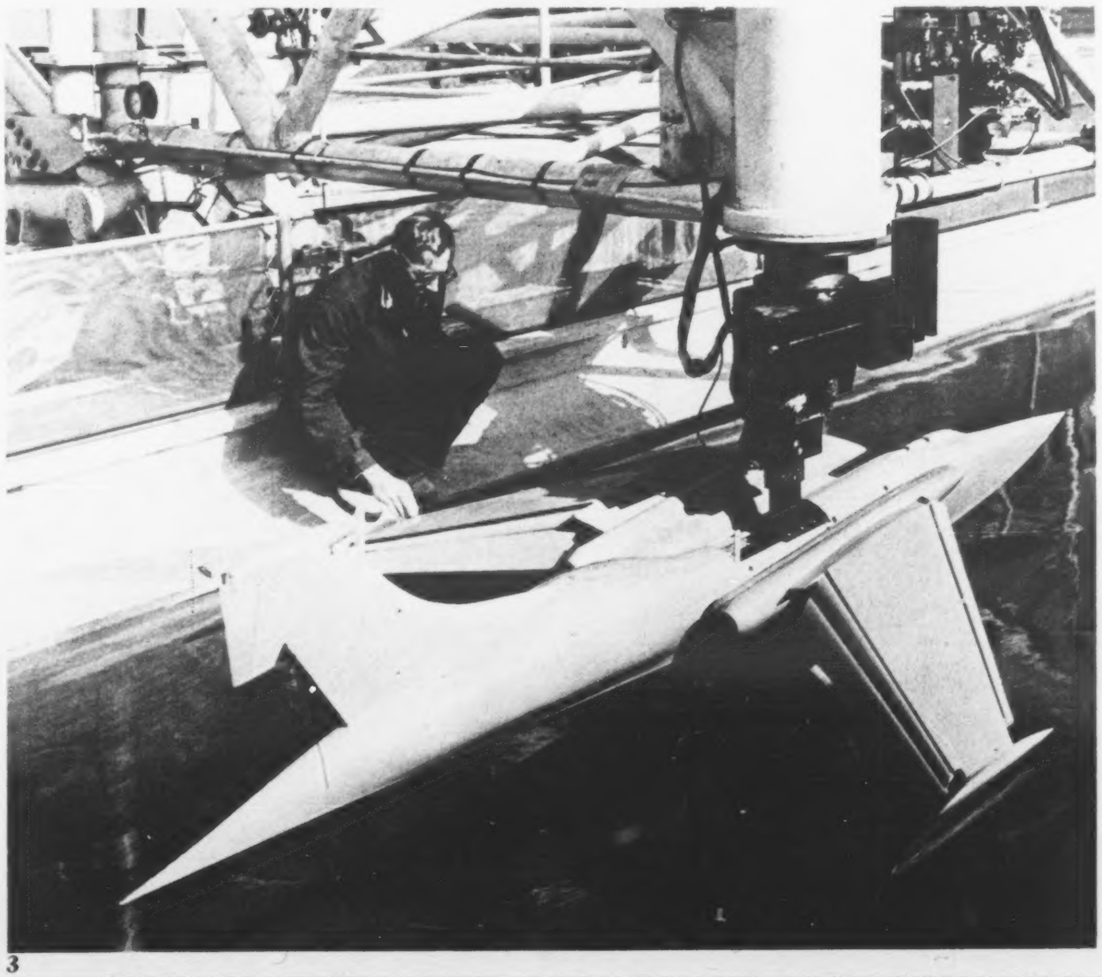
The velocity-gravity-altitude (VGH) recorders, installed in many aircraft, produced data that was used in 1950 to make a worldwide analysis of atmospheric turbulence and gusts to guide aircraft designers in accounting for these perturbations in otherwise-steady flight regimes.

The flexible wing, an entirely new concept of lifting structure, was conceived just after the war at Langley. Patented in 1948 as a kite, the flexible wing has grown into a remarkable variety of applications where lift-drag ratios need not exceed 3.0.

This decade saw the sophisticated development of one of the flight researcher's most useful tools: The flying-model technique.

This grew out of earlier work in the free-spinning tunnel, where dynamically similar models of aircraft were forced to spin in a a vertical tunnel test section, and the behavior was photographed and observed.

The idea of the free-spinning tunnel was extrapolated to a free-flight tunnel during the mid-1930s. The technique was one way to obtain dynamic stability and control



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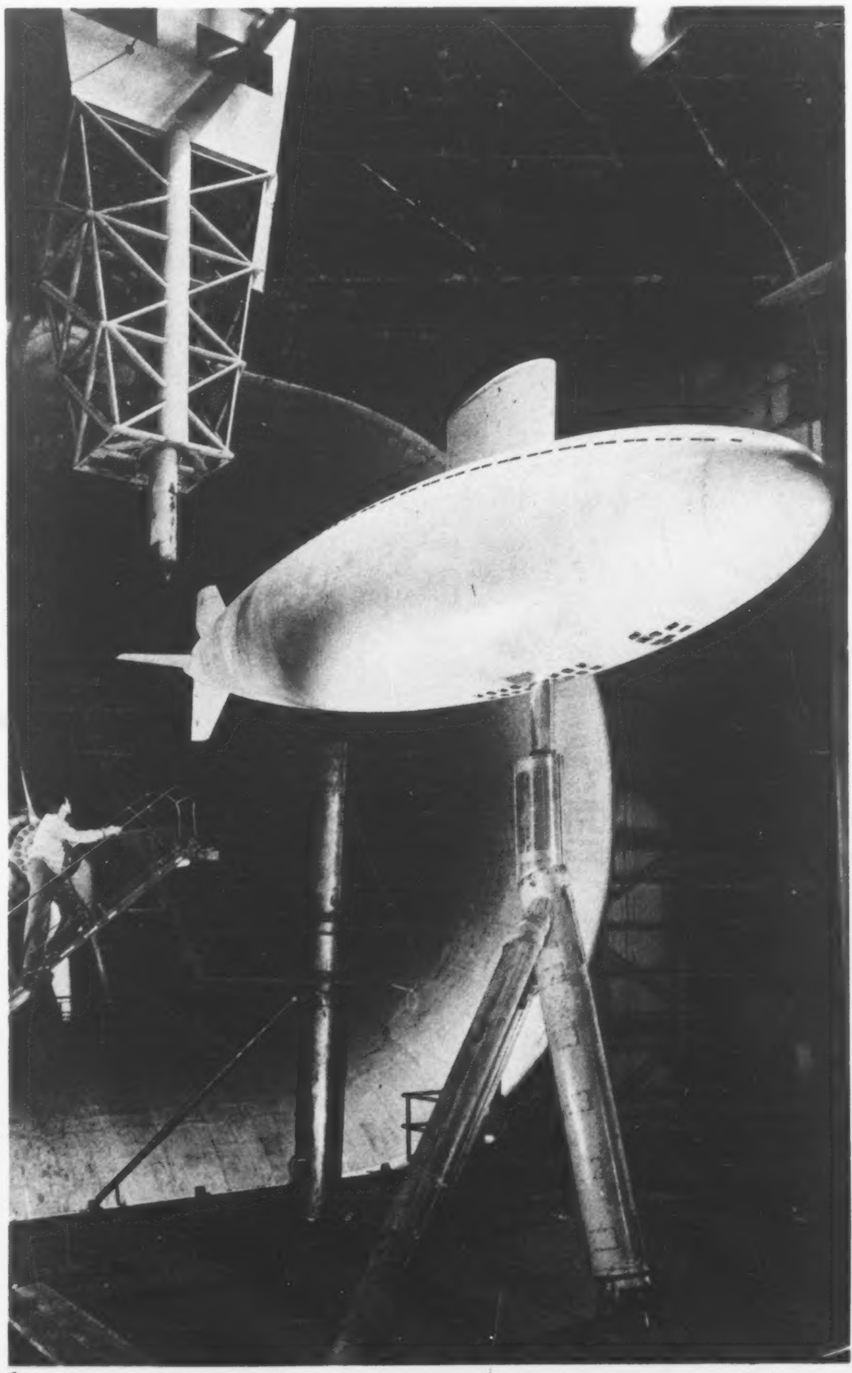
1. Structures research at Langley included studies of methods to control failures of pressurized fuselages.

2. Ground loads on high-speed aircraft landing gears are checked on this hydraulic-jet propelled carriage at Langley's Landing Loads Track facility.

3. High-speed jet-propelled seaplane studies were made at Langley.

1. The submarine Albacore, then the world's fastest, was tested in model form in the Langley full-scale tunnel in 1950.

2. Models of the Convair F-102 before (left) and after (right) application of the area rule were flight-tested from the Pilotless Aircraft Research Station at Wallops Island, Va.



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characteristics on a small-scale remotely controlled model. By 1937 a small tunnel had been developed which was a pilot model for later tunnels to come.

The model work conducted in this primary facility led to the construction of the 12-foot Free-Flight Tunnel, which started operating at Langley in 1939. That tunnel was used until the early 1950s, when an improved technique was developed and applied in the Langley Full-Scale Tunnel. That technique, using remote-controlled, powered models, is used to determine low-speed dynamic stability and control characteristics. It is primarily a qualitative evaluation, and the data is in the form of pilot opinion and motion pictures of the behavior of the models.

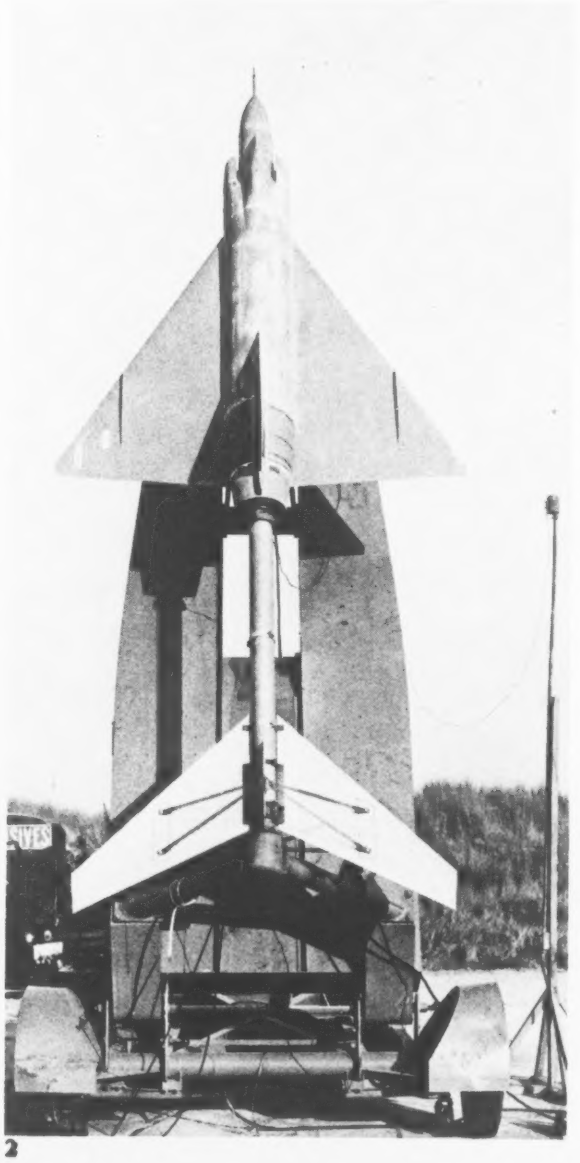
Other free-flight techniques were adapted at Langley during this time period, including the model airplane enthusiasts' U-control ideas. Langley's Control-Line Facility started operation in 1955 primarily to increase research capability in studies of transition of VTOL aircraft. Rapid transitions from vertical to horizontal flight, and back again, can be made with the control-line technique. Tests in the Full-Scale Tunnel are limited to very slow transitions because it takes a long time to change the speed of the air stream in the tunnel.

The end of the decade saw the beginning of serious work on hypersonic research. The X-15 program was one manifestation of the drive to investigate the upper reaches of the supersonic flight regime and on into the hypersonic.

In 1955 Langley, along with Ames Aeronautical Laboratory, began to develop a series of high-temperature facilities for materials and structures research. High-temperature problems had been singled out as the main barrier to the successful achievement of hypersonic flight, and NACA wanted to break down that barrier.

At Wallops Island, Langley was developing and firing multiple-stage rocket vehicles, aimed at higher speeds and altitudes. On August 24, 1956, the division launched successfully a five-stage, solid-propellant rocket vehicle. It reached a speed of Mach 15, far into the hypersonic region and beginning to touch the Mach numbers that would be encountered in ballistic missile re-entry bodies and in the return of men from space.

At the Langley Structures Research Division, work began during 1956 on the arc-jet facilities whose abnormally high temperatures generated the environment of re-entry flight. Two dozen of these arc-jet facilities subsequently were developed and



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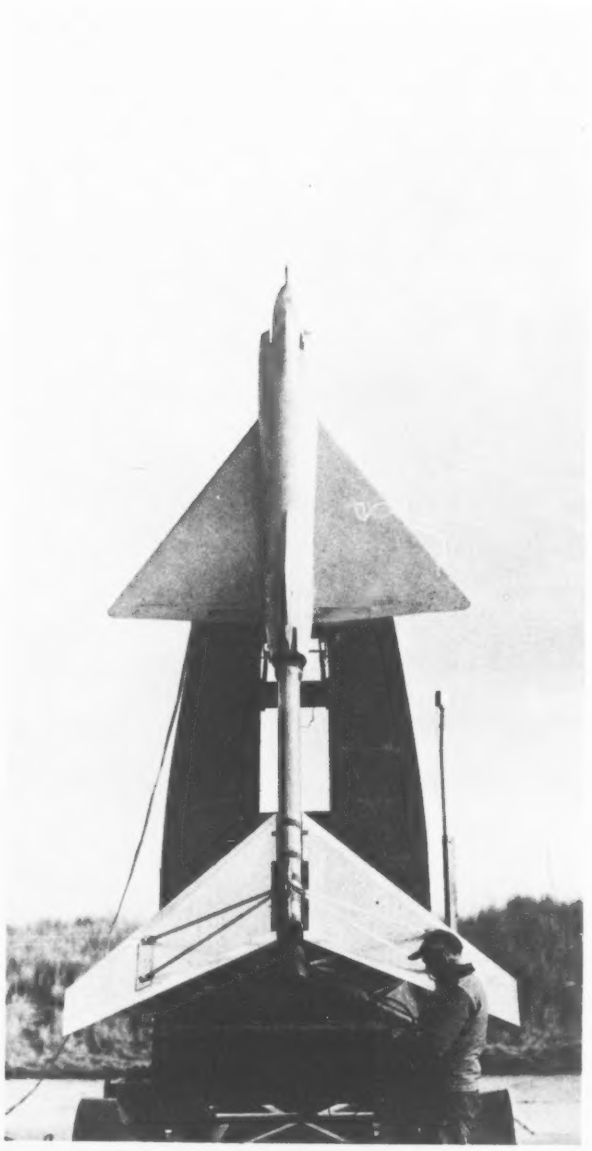


used in research on materials and structures for re-entry.

During July 1957, Langley engineers began studies of the use of solid-fuel rockets to launch and orbit a small payload. The purpose was to develop an inexpensive launching vehicle that could be used for scientific satellite work.

What resulted finally from this work was the concept and development of the Scout, a solid-propellant launch vehicle that has been responsible for lifting many scientific payloads into space for government, private industry and foreign government space efforts.

Late in 1957, Langley proposed the basic ballistic form for re-entry from space that was later to become the characteristic shape of the Mercury capsule. Winged and wingless glider configurations for manned spacecraft also were proposed, and later would become incorporated in the Dyna-Soar and the Apollo programs.

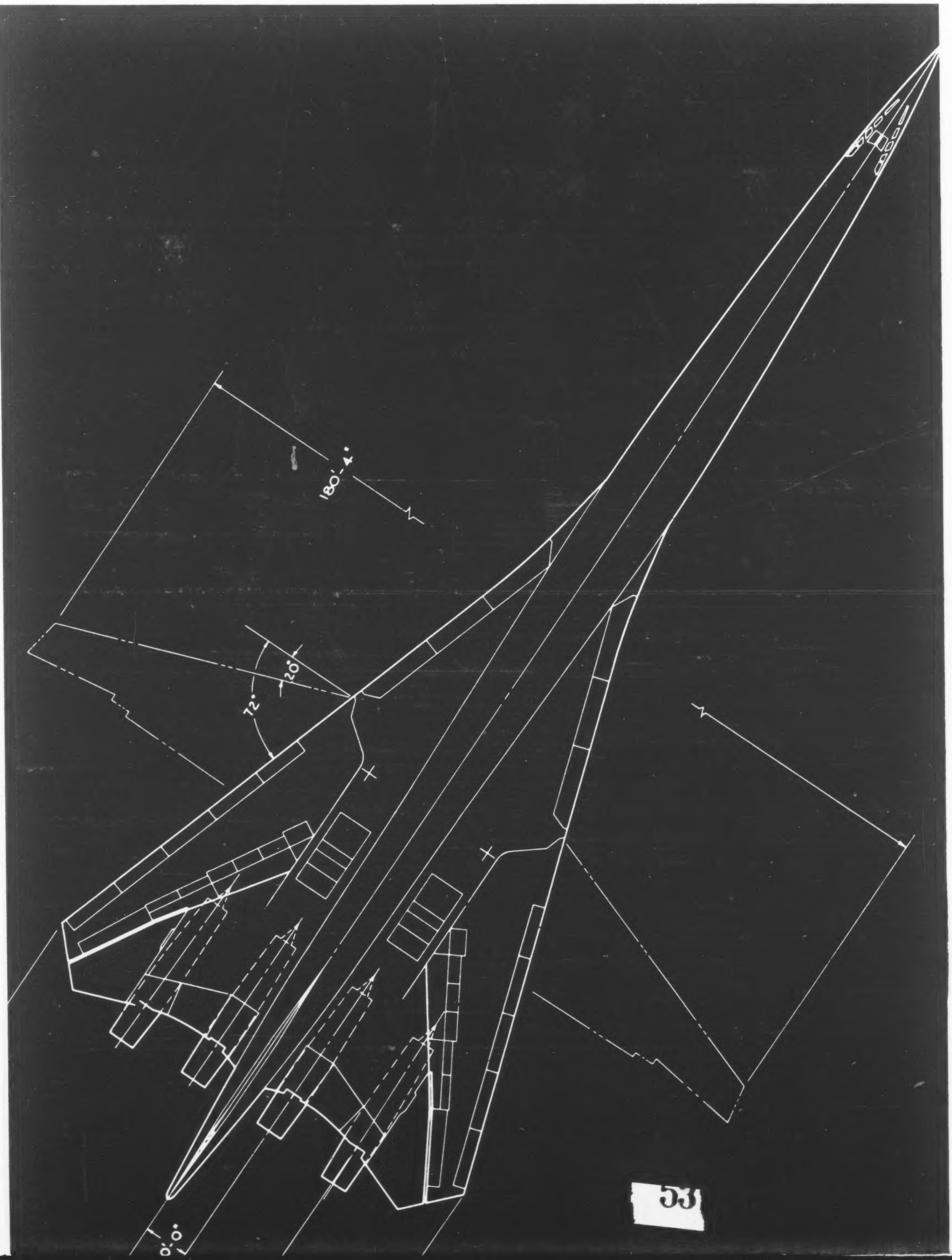
This decade started with the first probing of the supersonic region by a manned aircraft. It progressed, rapidly, through routine supersonic flights by military pilots in standard service aircraft.

The decade drew to an end with the sudden awareness of the importance of space flight and the use of space for exploration and defense. Sputnik spurred the rapid development of ideas for vehicles that could get men into space and return them safely in the searing heat of re-entry.

The aeronautical techniques developed over the years were soon to be placed in the service of a new technology whose environment was airless, where winged flight was impossible, where aerodynamic controls were useless, and where turbojet engines could not maintain their internal burning.

But those aeronautical techniques were to become among the most important contributions to the success of manned spaceflight, because what went into space had to pass through the atmosphere on its way there. And what was to come back from space had to traverse the atmosphere in the fiery rush of its homeward voyage.

Langley's work was predestined for the next decade.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1958-1967

To comprehend aviation's rate of growth during the past decade, look back to 1958. Sputnik had just been launched, but the world's air travel was being done in piston-engined airplanes cruising at speeds comparable to those of World War 2 fighters.

There were no jet transports in operational service. The giant airliners of the day carried 70 passengers. More people crossed the Atlantic by ship than by air.

There were no astronauts. Man had yet to see his own planet from a height greater than a few miles. The moon was still as far away as the sun, in terms of what was known about it.

The exploration of space was being done at its lower fringes with sounding rockets fired vertically into the upper atmosphere. A few pioneering divers, with self-contained breathing apparatus, were finding the depths of the ocean to be a new frontier for exploration.

But in 1967, the jet transport dominates the airlanes of the world, carrying as many as 250 passengers at high subsonic speeds and altitudes near the stratosphere.

Under construction are giant transports, that can carry up to ten times the number of people who sat in the airliners of a decade ago. The supersonic transport, now under construction, will cruise the world's air routes at speeds more than three times those of the first jets, and more than six times as fast as the piston-engined transports of a decade ago.

Trans-Atlantic ship travel is almost negligible compared to trans-Atlantic air traffic.

Astronauts have orbited the earth, walked in space, performed manual labor in the void, photographed earth from altitudes of hundreds of miles. Unmanned satellites and probes have landed on the Moon, photographed its unseen side from lunar orbit, surveyed possible landing sites on its surface.

The oceans of the world have begun to yield to scientific and systematic exploration, made possible in many instances by the same technologies that helped to conquer first the air and then space.

Ten years ago, jet propulsion and sweptback wings were for military aircraft only, and for the first few jet transports that were entering training programs with the airlines of the world.

Vertical takeoff and landing aircraft were freaks, with freakish performance in most cases, and far removed from the possibility of deployment with a military service.

Supersonic flight was the province of a few military pilots, and the majority of supersonic flight time was being logged well below Mach 2.0.

Titanium was a strange word, and the amount used in aircraft construction could be measured in pounds rather than larger units.

But gradually, the tangible evidence of progress began to show. In October 1958, jet passenger service was started across the North Atlantic by British Overseas Airways Corp., and that year, for the first time, more passengers crossed the Atlantic by air than crossed by ship.

In 1960, the Apollo project was officially announced, and the Echo satellite, an inflatable balloon for space flight, was launched successfully.

Cdr. Alan B. Shepard, Jr., became America's first astronaut with a sub-orbital flight as part of Project Mercury in 1961.

Four pilots of the X-15 research aircraft won the Collier Trophy for 1961: Maj. Robert White, USAF; Cdr. Forrest Petersen, USN; and two civilian pilots from the National Aeronautics and Space Administration, Scott Crossfield and Joseph Walker.

In June 1963, President John F. Kennedy announced that the United States was going to develop a supersonic transport. In France and Great Britain, a European consortium of aircraft manufacturers already was hard at work building a supersonic transport, still scheduled to fly early in 1968.

On Dec. 17, 1963, just 60 years after the Wright brothers took to the air in hesitant flight over the sands of Kitty Hawk, Lockheed flew for the first time its newest heavy cargo carrier, the C-141A.

Other labors at Lockheed were unveiled to an awed public when the A-11 was announced early in 1964. This Mach 3 airplane possessed much of the technology that could contribute to the development of a supersonic transport, especially in the knowledge of the problems of sustained flight at the tri-sonic speed which was the goal of the U. S. SST program.

The XB-70 made its first flight, even though the aircraft was obsolete from the day it rolled out of the factory into the bright California sunshine. Two aircraft, which owed much of their *conceptual designs and development work to Langley, made first flights in 1964: The General Dynamics F-111, a variable-sweep fighter, and the tri-service VTOL transport, the XC-142A, built by a consortium of Ling-Temco-Vought, Ryan and Hiller.*

This 50th year of Langley opened with another landmark event in aviation. In January, contracts for development and construction of the U. S. supersonic transport were awarded to the Boeing Company, for the airframe, and the General Electric Co., for the powerplants.

To the scientists and engineers at the Langley Research Center, this decade has seemed a little like the situation that faced Alice, when the Red Queen told her that she had to run as fast as she could just to stay in the same place.

Somehow, the work done at the Langley center seemed to run that extra bit faster, so that it could pace these developments in aviation. And this was done in spite of the necessary turmoil created by the complete change in organization that occurred in 1958 with the formation of the National Aeronautics and Space Administration from the National Advisory Committee for Aeronautics and other organizations.

Langley Research Center, once the only laboratory for NACA, now is one of several. But it has made possible, over the years, formation of other laboratories which found their origins at Langley.

The Lewis Research Center, where powerplant work is the primary objective, had its roots in the engine laboratory opened at Langley in 1920.

The Ames Research Center was started with a nucleus of Langley personnel, and now shares a portion of the development work in aeronautics and space flight.

The offshoot work at Wallops Island now is a full-fledged program which encompasses rocket vehicles and flight-test aircraft in a self-contained organization.

The group that went to Muroc Dry Lake to help in the flight-test work on the Bell XS-1 grew into the Flight Research Center, formed around the core of Langley people.

In Houston, Texas, a complete new center has sprung up which almost dwarfs the other operations of NASA. The Manned Spacecraft Center, as it is now, originated as the Space Task Group at Langley.

Familiar names from the Langley personnel rosters dot the organization charts of these later centers. Familiar techniques learned and developed in the wind tunnels and other facilities at Langley have been extrapolated to solve the advanced problems of space flight. Familiar facilities which once tested scale models of unswept wings and piston-engined aircraft now blast air at the latest shapes of lifting bodies for recovery of astronauts from earth orbit.

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The progress of this decade has been built on the strong foundations of the Langley Research Center.

No one action triggered the explosive growth of space programs in the United States more than the Russian launching of the Sputnik I.

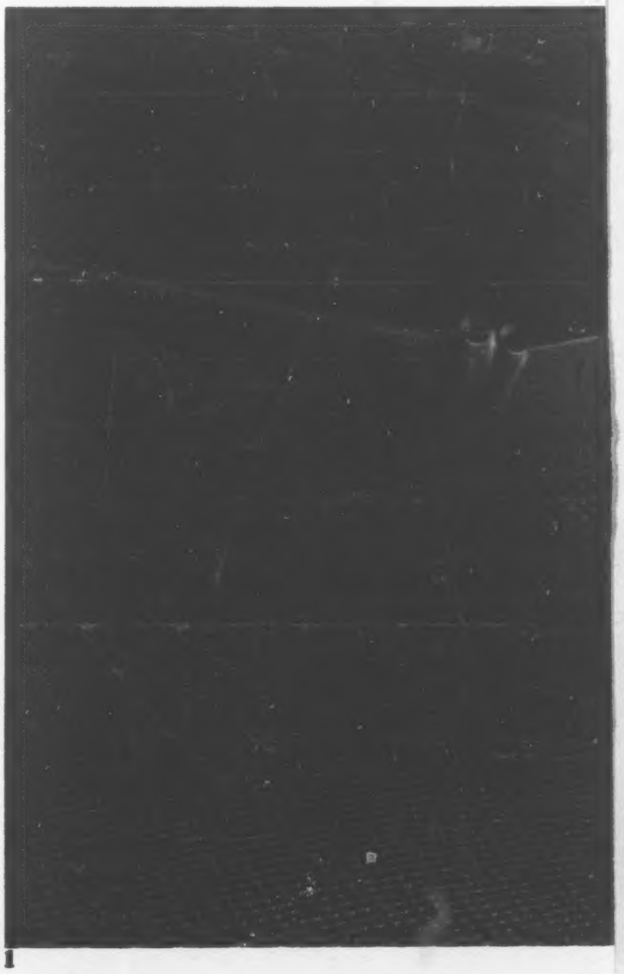
Hardly a month passed after its successful orbiting when President Dwight D. Eisenhower announced the appointment of Dr. James R. Killian, President of the Massachusetts Institute of Technology, as a special science advisor to the White House.

This was followed by a Congressional investigation of the U. S. missile and space programs and the formation of special committees in both houses of Congress charged with the responsibility for space affairs.

The American Rocket Society and the National Academy of Sciences joined in recommending the creation of a National Space Establishment.

In January 1958, the President's State of the Union message to Congress told of the creation of the Advanced Research Projects Agency to gather together all of the anti-missile and satellite activities in the Department of Defense.

Later that month, the Senate Preparedness Investigating Subcommittee submitted a unanimous report which asked for the creation of an independent space agency and the organizational overhaul of all missile and space programs in the Dept. of Defense.



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The President's Advisory Committee on Government Organization recommended that all non-military space activities be gathered together into a civilian space agency, using as its foundation the National Advisory Committee for Aeronautics. President Eisenhower approved that recommendation on March 5, 1958, and on April 2, 1958, sent his bill for the establishment of the civilian agency to the Congress.

Between then and July 16, Congress developed the legislation that was to become the National Aeronautics and Space Act of 1958. It was signed into law by President Eisenhower July 29, 1958.

In part, Eisenhower's statement on the signing of the bill said:

"The present National Advisory Committee for Aeronautics (NACA) with its large and competent staff and well-equipped laboratories will provide the nucleus for NASA . . . The coordination of space exploration responsibilities with NACA's traditional aeronautical research functions is a natural evolution . . ."

Eisenhower nominated Dr. T. Keith Glennan to be the first Administrator of the new National Aeronautics and Space Administration and NACA Director Dr. Hugh L. Dryden to be the Deputy Administrator. Their nominations were approved and confirmed by Congress; the appointees were sworn in

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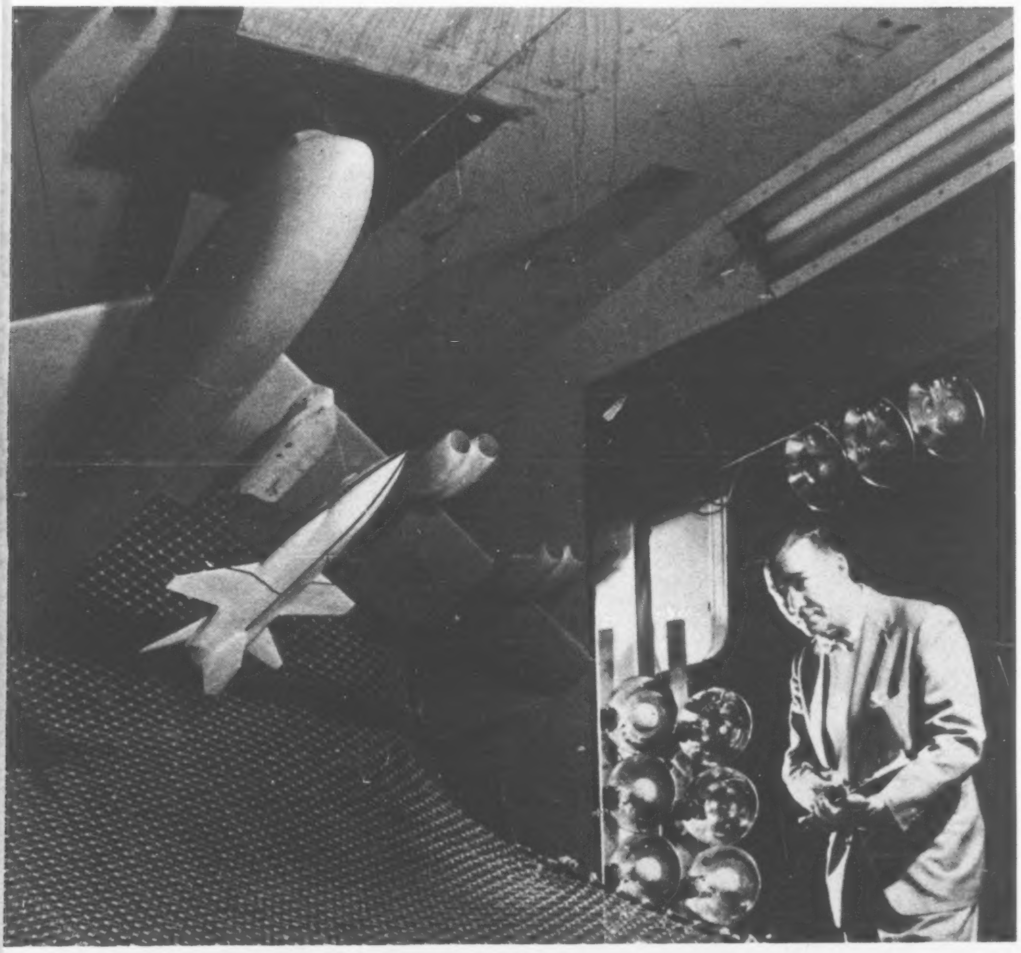


1. X-15 launch technique was investigated in the seven by ten-foot wind tunnel at Langley with one-twentieth scale models.

2. X-15 model in Langley supersonic tunnel.

August 19, attended the last meeting of NACA two days later, and—on October 1—opened the new agency for business.

There already had been evidence that the natural evolution Eisenhower referred to in his statement was no figure of speech. Before the establishment of NASA, manned satellite programs had been considered by NACA scientists, and the work had gone far enough to recognize some of the problems of the re-entry of manned vehicles from orbit. Three solutions had been proposed: The ballistic capsule with heat shield, the hypersonic glider, and the lifting body.

During the years since the establishment of NASA, Langley scientists have continued to make major contributions to the science of space flight, to develop unique test facilities for better understanding of the problems, and to adapt existing test facilities to new uses.

NASA was assigned responsibility for the U. S. manned space flight program in August 1958. In its first week of existence, NASA organized the Space Task Group, and based it at Langley. It included 45 scientists from the Langley and Lewis Research Centers.

Many of the Langley members of the Space Task Group staff were no strangers to the problems of manned space flight. Before the Group was organized, they had developed the concept of the "Little Joe" test vehicle, which became a workhorse of the Mercury program; they had shown the feasibility of a manned satellite program, using existing intercontinental ballistic missiles for launch vehicles and the ballistic re-entry shape as the crew capsule. And the contour couch concept—later used in all the space capsules' crew positions—had been conceived and built at Langley, and tested to prove its feasibility.

They had drafted the preliminary specifications for what was to become the Mercury program in June 1958; when they were appointed to the Space Task Group in August, they were ready to go.

After that date, they designed the "Big Joe" test vehicle, proved the feasibility of the ablative heat-shield, and developed procedure trainers for the Mercury astronauts which were the foundations for the complex simulators of later space flights. In support, Langley Research Center took on the responsibility for planning and contracting for the Mercury tracking network.

Langley scientists developed supporting programs for manned space flight such as Project Fire, which investigated the heat of re-entry and its effects on materials; Project RAM (Radio Attenuation Measurements) which focussed on the problems of transmitting through the plasma sheath formed around a re-entering spacecraft; and the development of infra-red sensors to tell a spacecraft which way was up.

The automatically inflating satellite, like the huge Echo balloon, was a Langley concept and development; so was the inflatable space vehicle, which was one approach to the problem of housing men in an orbiting laboratory.

Re-entry speeds as high as Mach 26 were achieved in multistage rocket firings from the Wallops Station in a study of the problems of that unique phase of space flight.

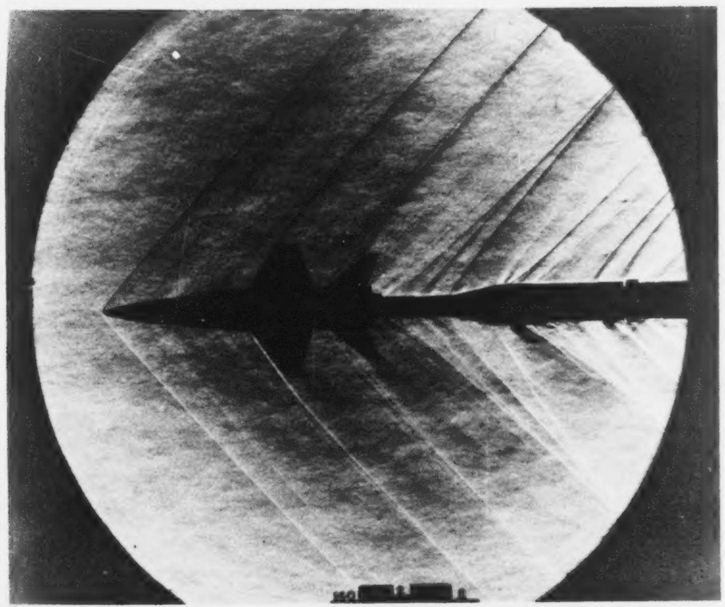
The concept of rendezvous and the staging of a space flight from an initial established orbit was studied by Langley scientists who established the value of the lunar-orbit rendezvous, which is the foundation of the entire Apollo program, and which made the Apollo program feasible with the available sizes of launch vehicles and crew capsules.

More recently, the highly successful Lunar Orbiter series of exploration satellites, designed to transmit topographic information about the lunar surface, was conceived at Langley and the development program managed by Langley scientists.

Project Mercury grew into Project Apollo, in which the first announced goal was simply to sustain an orbit around the earth or the moon with a multi-man crew. It was later expanded to tackle the job of manned lunar exploration, and Project Gemini was established to solve some of the problems of orbital rendezvous and docking that would characterize the advanced phases of the Apollo program.

This is properly a history of aviation and the developments and contributions of the Langley Research Center to the sciences of aeronautics. But these contributions of Langley to the space effort were summarized here because they illustrate how the basic knowledge of aeronautics, acquired over the years, has evolved into solutions to the problems of space flight.

More than that, they show that Langley was able to make major contributions to the space programs while still maintaining its leadership in aeronautical research. The handling of such diverse programs as the responsibility for a massive electronic network for tracking a spacecraft in orbit, or the development of an inflatable space vehicle, is a tribute to the organization of the Langley Research Center.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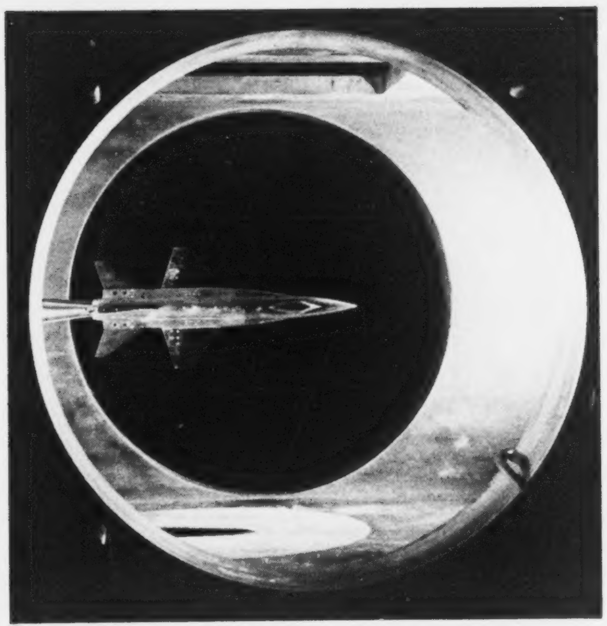
1. Shock waves festoon a small scale model of the X-15 in Langley's four-by four-foot supersonic pressure tunnel.

2. X-15 model in Langley supersonic tunnel.

3. New ablative coating for X-15 changes plane's color from black to white.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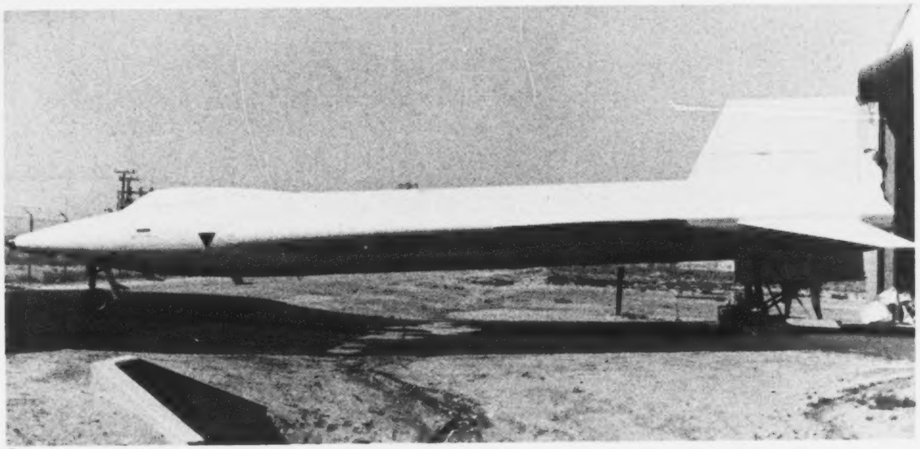
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These tasks were often under scientists who worked on a space problem for one week and then switched back to aeronautical tasks or to re-entry physics. The work was done while the entire Langley staff was occupied with the problems of reorganization under NASA, with the pressure of expanding staff and facilities, and with the problems of contracting for and monitoring or managing programs with outside industrial contractors.

The basic studies of supersonic cruise aircraft configurations that Langley had been pursuing for some years began to point toward two major areas early in this decade. First of these was the multi-mission aircraft, a concept of a design that would be equally efficient at high and low speeds, and at high and low altitudes. This thinking led ultimately to the current form of the variable-sweep wing.

The other area was the development of configurations for a supersonic transport which found application to the Boeing design chosen for development early this year.

In support of both these programs, specific solutions were found to many of the perplexing problems of sustained supersonic flight. For example, the studies on air inlets, nozzles and exhaust configurations, made in the Langley tunnels, have been adapted by industry to the designs of the latest military aircraft. Base drag studies, initiated as part of the TFX (later F-111 development), made a major contribution in the drag reduction program for that airplane.

It took a while before the programs got this specific, however. In the early months of this decade, the work on variable-sweep was almost entirely confined to comments, discussions and tests on the variable-sweep

Swallow concept, developed in Great Britain.

The Swallow concept was encouraged by Langley personnel who were asked to comment, and became the initial basis for a proposal for a joint research program.

The 16-ft. transonic tunnel was to be used for some tests of the jet exits, and other tests, featuring a Langley-suggested modification of the Swallow, were to be made. Langley took on most of the job of constructing the model and conducting the wind tunnel programs. The decomposition process of hydrogen peroxide was used to simulate jet effects in the tunnel tests, and the Langley model of the Swallow is remembered today as one of the most complex ever tested at the laboratory.

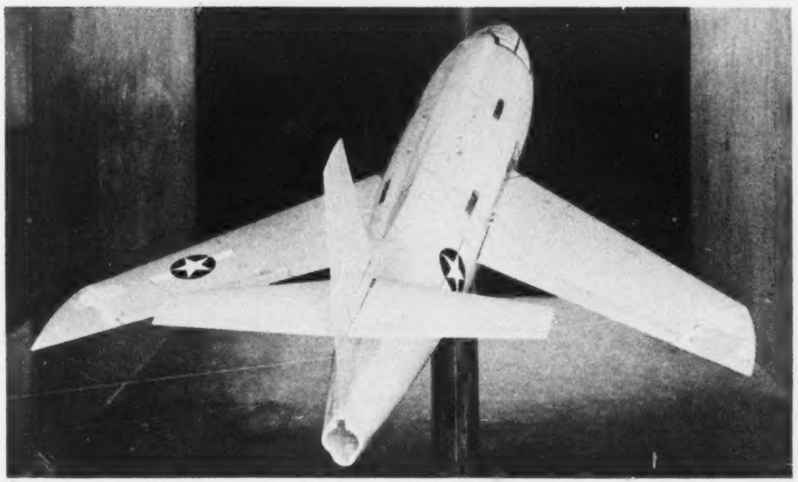
For various reasons, the Swallow work was dropped in favor of a configuration with engines in the fuselage, and tests were continued to study the characteristics of variable geometry.

The tests that had been made on variable-sweep models indicated that they all suffered from major changes in stability as the wings were swept. This was the reason that the Bell X-5 and Grumman XF10F-1 wings were translated forward as they were swept aft.

This was a mechanical complexity that NASA engineers believed they could do without, and their testing aimed toward that goal, among others.

Parallel analytical studies on span-loading done at Langley showed that if the pivot points were moved outboard, instead of being on the centerline, the stability variation could be reduced considerably. Some experiments were done on a model of this kind of configuration and they proved the basic idea. It was to be the key to the success of the variable-sweep idea.

The outboard pivot made it possible to sweep the wings through a large angle without any need for translation. Further tests showed that supersonic cruise performance potential was practically as good as the best design-point cruise configurations developed earlier. Mach number for Mach number, there was little to choose from between the variable-sweep airplane with outboard pivots, and the best fixed-wing



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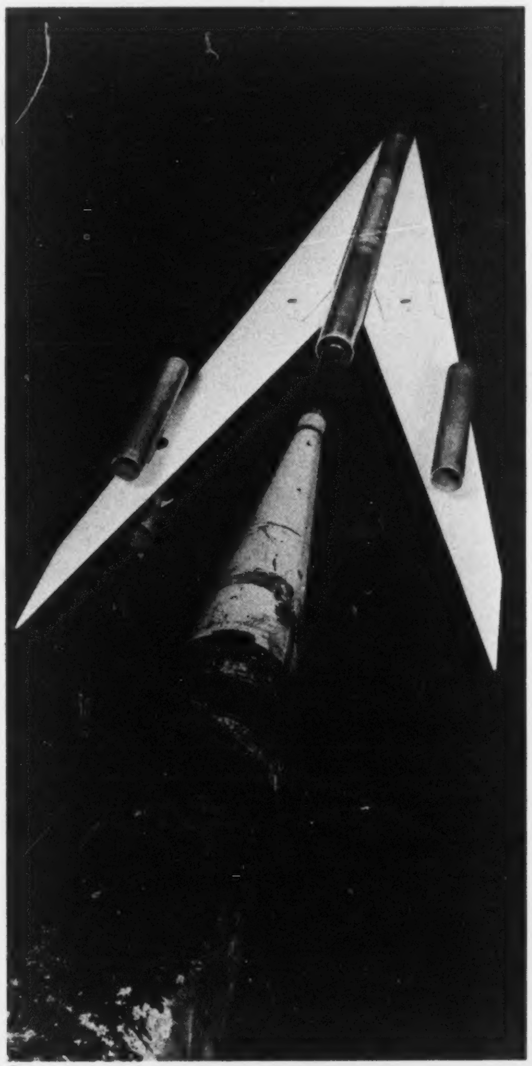

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1. Modified Bell X-1 model pioneered variable-sweep studies in 1947.

2. British "Swallow" concept of variable-sweep was tested at Langley.

3. Model of proposed military supersonic attack airplane shows wing sweep range.

arrangement that could be devised.

In mid-1959, the Navy was considering an aircraft for a combat air patrol mission, and NASA conducted a briefing for top Navy officers and staff on the variable-sweep configuration studies that had been developed to that point. They were applied to the layout of a Naval aircraft weighing 50,000 lb. which was to be capable of doing the combat air patrol mission plus high-altitude attack, and low-level strike missions. The concept of the multimission aircraft seemed feasible, in the light of the available data on variable sweep.

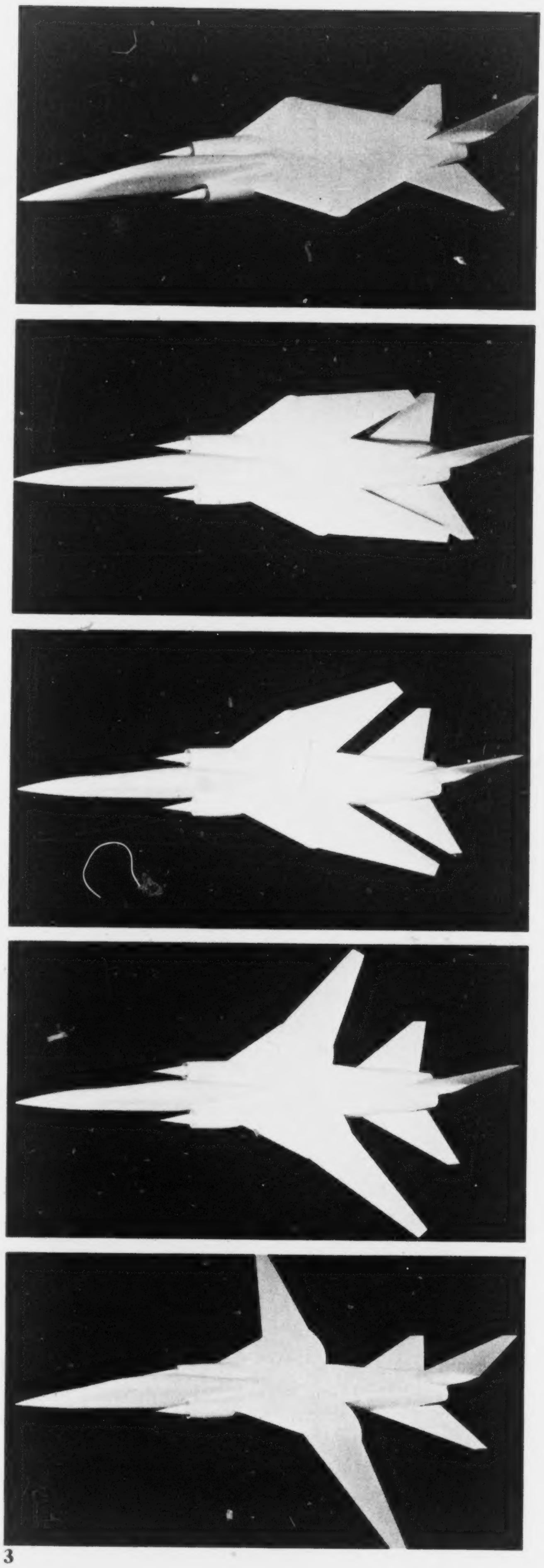
The Navy airplane, even though it was a paper design based on limited wind-tunnel data and a paper engine, showed so much performance potential that it completely outclassed any weapon system then being built or planned.

The briefing was repeated for the staff of the Air Force Tactical Air Command Headquarters, just across Langley Field, and they suggested that the general staff receive the same briefing. This done, NASA teams presented essentially the same material in a series of briefings to industry. They talked to eight major aerospace contractors in less than one month, acquainting them with the concept and summarizing the research.

Before mid-August 1959 Langley received a letter stating that the Air Force Research and Development Command was being asked to "take a further more detailed look at your variable-sweep design concept as a possible solution to Air Force requirements."

A second round of briefings, presenting some new data, was made to industry between September 1959 and January 1960. During a Navy briefing, Langley scientists pointed out that the full potential of the variable-sweep design would best be realized if there were a completely new turbofan engine around which to build the airframe.

Development work continued at an accelerated pace, and began to center on the requirements of Tactical Air Command for a fighter with extremely high performance at low altitude and the capability of extremely long range. Langley developed a series of design layouts, paralleling a similar design study done by the Air Force. The four models were completely designed in detail of aerodynamic configurations; scale models were built in the Langley shops, tested at transonic speeds in the eight-foot transonic pressure tunnel, and the data analyzed and flown to the Air Force at Wright Field—all in the time of 13 days. It was called Project Hurry-Up, and it lived up to its name.



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Briefings, a second phase of "Hurry-Up", more analyses, studies and tests followed rapidly. Free-flight tests were made with a model of one of the Navy configurations in the full-scale tunnel, in a pacemaking experiment in the development of variable-sweep aircraft. Sweep angles were varied from 25 deg. to 75 deg. during flight, and no extraordinary problems, either of stability or control, developed.

This work, the requirements of the Navy and the Air Force, and the studies conducted by the military services and industry finally coalesced in February 1961. Secretary of Defense Robert S. McNamara ordered that the requirements of the Army, the Navy and the Air Force be combined into a tri-service tactical fighter.

The detailed story of the TFX program, as it was first called, and its evolution into the F-111 fighter design, has been told before. Langley's part in the program was played from the start, in the development of the concept of variable-sweep that made the multi-mission aircraft—of which the F-111 was intended to be only one example—feasible. Later Langley studies provided refined design data and evaluations for the military and industry. Finally, Langley engineers attacked specific problem areas in the chosen design even after prototypes had been built and flown.

The work continues today, applied to other studies as well as to those relating to the F-111. Part of those other studies center on the supersonic transport.

Late in 1959, a team from Langley Research Center summarized the technical status of the supersonic transport in a Washington briefing for Lt. Gen. E. R. Quesada, then the head of the Federal Aviation Agency.

The point in time of the presentation was just after a round of detailed briefings of the military and industry on the potential of the variable-sweep concept. The introduction to the supersonic transport report stated that ". . . if the mission involved flight at only the design supersonic speed and crusing altitude, and if no emergencies occurred, intercontinental ranges of commercial interest and importance could be readily achieved. The intermediate range through which the airplane must perform to reach its supersonic cruise speed and altitude and to descend therefrom, however, imposes problems that must be solved. The research status as of today indicates that the proper solutions to the off-design problems can be provided through some form of airframe variable geometry—such as variable sweep—in combination with an advanced fan-type propulsion system. The present research position is that no fundamental problem appears with regard to these off-design conditions that cannot be solved by concentrated research effort."

This landmark report, published later as NASA Technical Note D-423, "The Supersonic Transport—A Technical Summary", went on to discuss the performance, noise, structures and materials, loads, flying qualities, runway and braking requirements, traffic control and operations, variable-geometry designs and possible areas for performance improvements.

The presentation signaled the time to begin serious work on development and construction of an SST. Within weeks the joint NASA-FAA program was well along, and within the year, the first contracts had been let for development of components for the power plants, pinpointed as the pacing problem in the SST program.

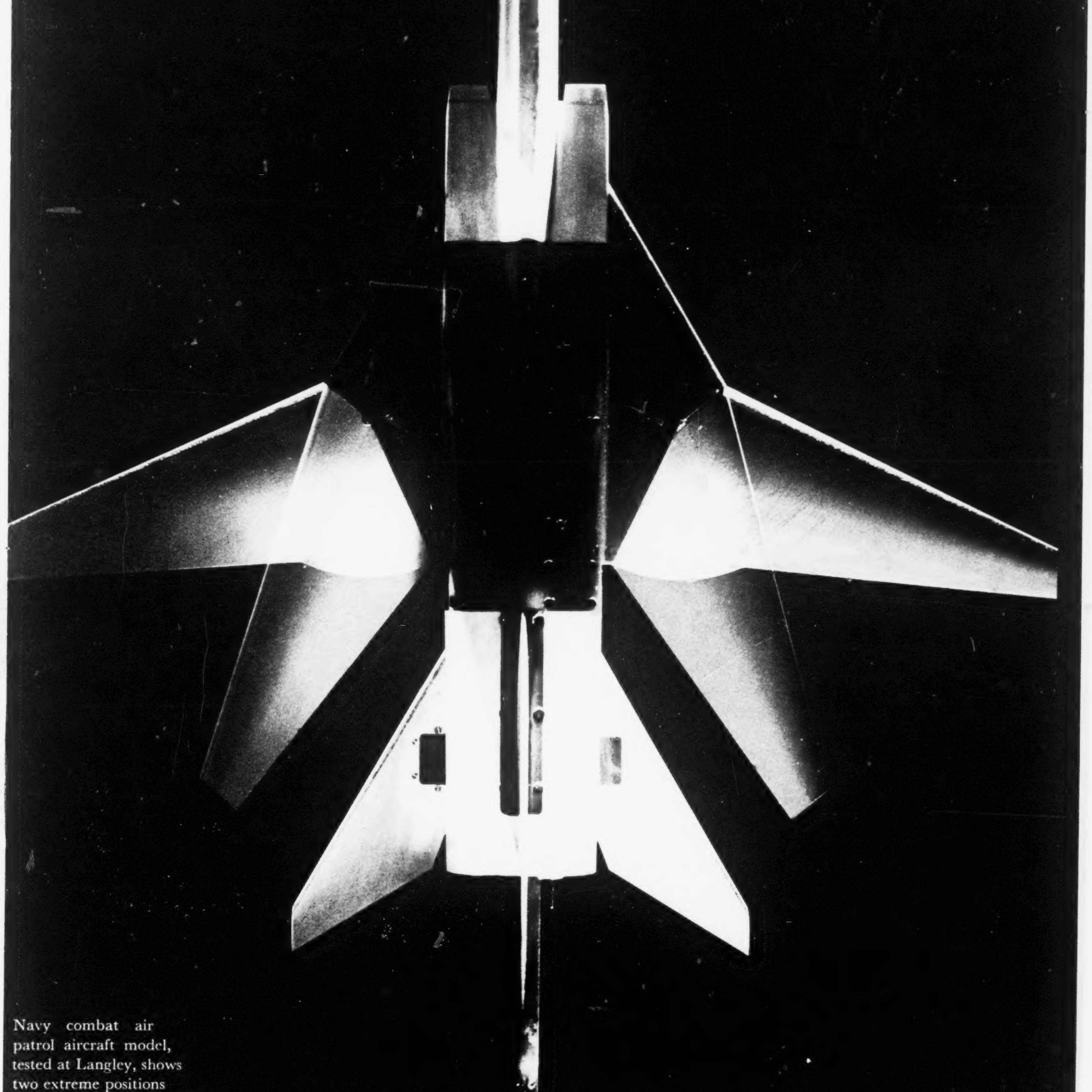
As in the case of the F-111, Langley has made many contributions to the development of the U. S. supersonic transport. Langley scientists have advised on the multitude of problems, conducted theoretical and experimental analyses, tested models in tunnels statically and in free-flight. But perhaps the major contribution of Langley to the SST program was its so-called SCAT series of configuration studies.

SCAT—which was an acronym standing for Supersonic Commercial Air Transport—started with program status at Langley sometime during 1962. Its purpose was to develop a configuration that would meet the unique requirements of a commercial SST over the anticipated performance range from takeoff through climb, cruise, descent, holding and landing. One goal, for example, was to develop a lift-drag ratio much greater than that of the B-70 at cruise. Other aims included the ability of the final configuration to operate at off-design conditions economically and efficiently.

The Langley studies settled down into two different approaches early in the program. One of these used a variable-sweep wing, and designated SCAT-15, it became one of the foundation stones of the entire SST program.

The other was SCAT-4, a fixed-wing proposal that carefully integrated wing, fuselage, engines and tail into a highly-swept, cambered and twisted aircraft design. The purpose was to minimize the wave drag due to lift, and this approach produced some design ideas that were later extended to other aircraft schemes, but have yet to see application to an actual design.

By early 1963, four SCAT geometries had



Navy combat air patrol aircraft model, tested at Langley, shows two extreme positions of variable-sweep wing.

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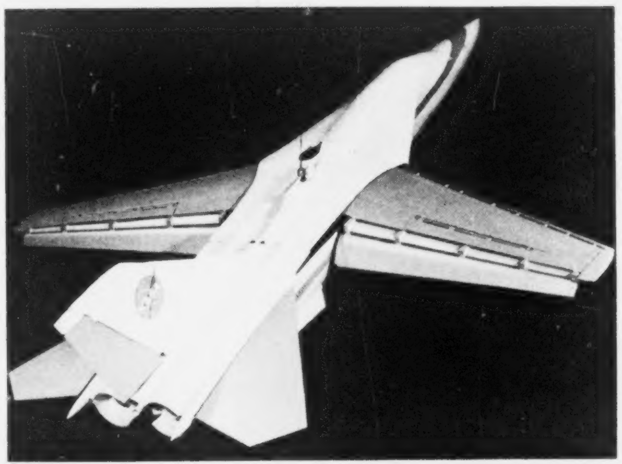

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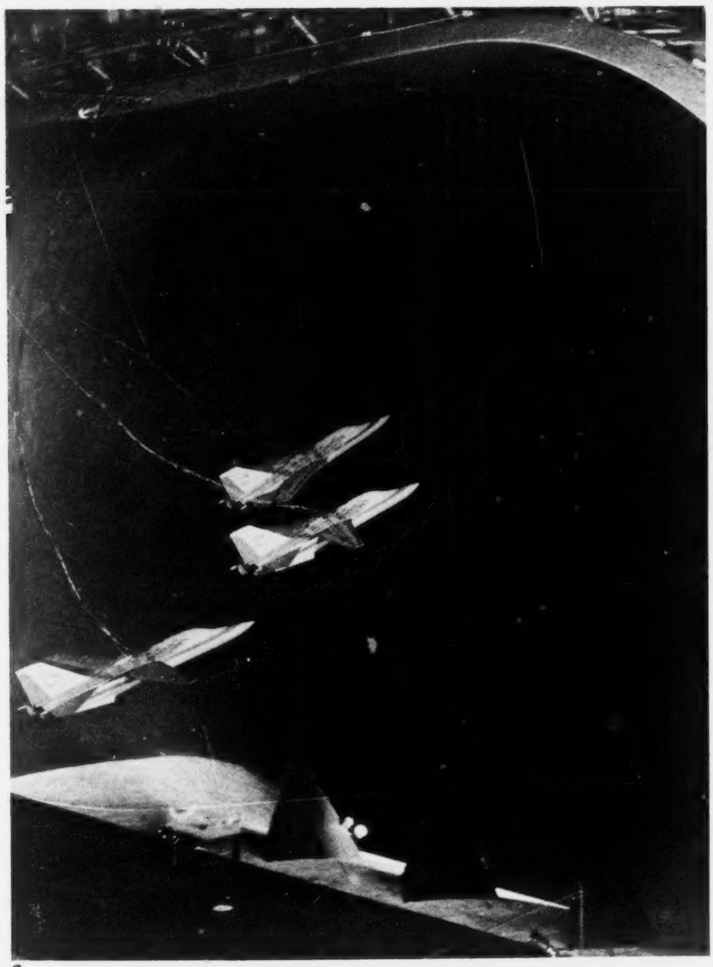

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1. Navy version of the F-111 variable-sweep fighter is surrounded by Langley test models of the basic fighter.

2. Built to fly, this model embodies all aerodynamic features.

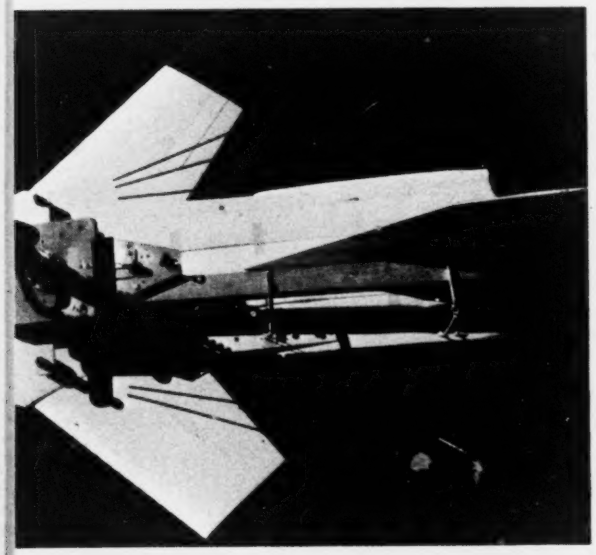
3. F-111 dynamic model in free-flight tests at Langley.

4. Wing sweep studies were made at Langley on this unpowered model of the F-111.

been selected as worth pursuing further. They included the SCAT-4 and SCAT-15, joined by SCAT-16, another variable-sweep proposal that evolved from the SCAT-15 work, and the SCAT-17, a fixed delta-winged layout with a forward canard surface. This latter version had been developed at Ames Research Center.

Industry investigations of these four configurations, done under NASA study contracts, showed that the SCAT-16 and SCAT-17 had the most favorable performance. They were to become the basis for the two competing configurations developed by Boeing and Lockheed.

There was a tremendous dividend paid by the SCAT and related configuration-study programs. Theory and experiment progressed side-by-side, with continuing feedback from one to the other. Gradually the theories were modified to allow for the real-flow conditions. As the aerodynamic efficiency of each design began to improve, so did the ability to predict that efficiency by theoretical means.



This narrowing of the differences between theory and experiment, began to yield the capability first, to optimize, and then, to predict, the aerodynamic characteristics of a wide range of aircraft.

During 1964, this ability to predict performance was developed into a computer program. In application to the SST designs, it became possible to predict the airplane polar diagram—a plot of the lift coefficient against the drag coefficient—within an accuracy of three percent. This aerodynamic revolution meant that a series of configurations could be investigated in a fraction of the time it formerly took. Small changes in design details could be worked into the computer program and their effects on overall performance predicted within a matter of hours. It formerly took weeks.

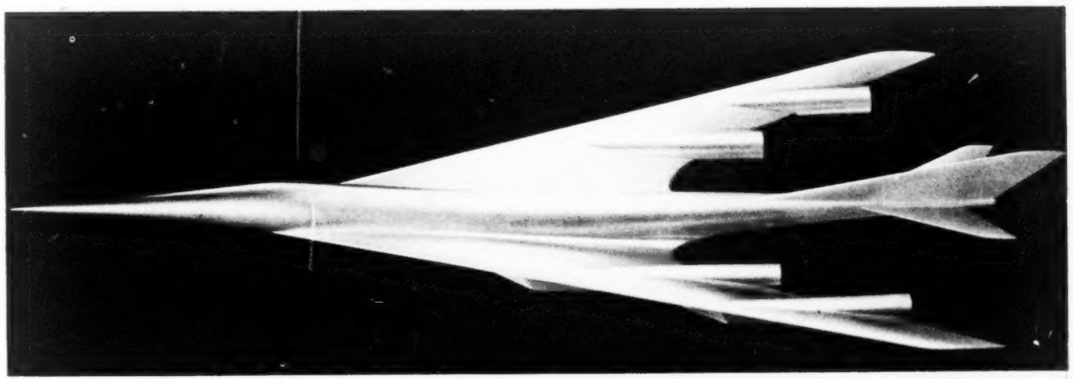
A further extension now makes it possible to use the same computerized approach to calculate the performance of a deflected airplane, that is, one that is distorted due to its response to the loads of maneuvering or of unsteady flow.

Finally, the computer program can be modified to produce an output which geometrically describes the airplane configuration under test. That output, converted to a punched tape, can be fed into tape-controlled machine tools to produce a wind tunnel model of the configuration study, again within a matter of hours.

But the cleanest of aerodynamic configurations with the minimum of wave drag still would produce a sonic boom. Langley researchers have been working on that problem in a variety of ways since the early stages of the SST program.

Their studies have been analytical and experimental, as is customary with many Langley programs. Measurements were made of sonic boom intensities in fly-bys of supersonic aircraft, and the results compared to theory. Tiny wind tunnel models, smaller than a tie-tack airplane, were built and tested in supersonic wind tunnels at Langley to determine the physical characteristics of the sonic boom and the parameters that caused and changed its nature.

Engineering ingenuity has made it possible to fly the supersonic transport before it is even built. The prototype Boeing 707-80, which had been utilized in the program of boundary-layer control, was further modified into a variable-stability airplane, whose handling qualities could be varied to simulate the approach and landing characteristics of the SST. Langley pilots flew the modified airplane in a series of tests to evaluate the parameters of the SST, and have analyzed the data for industry.



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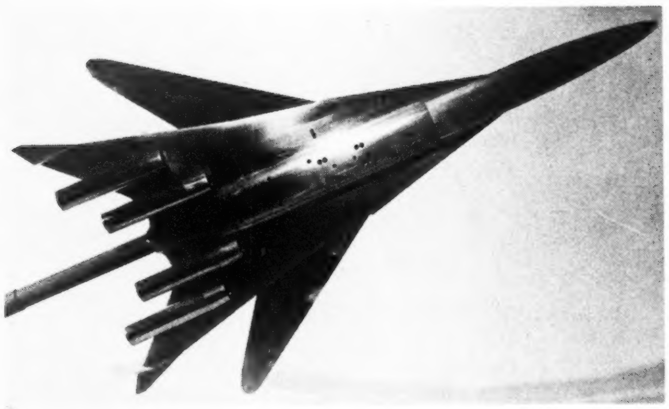

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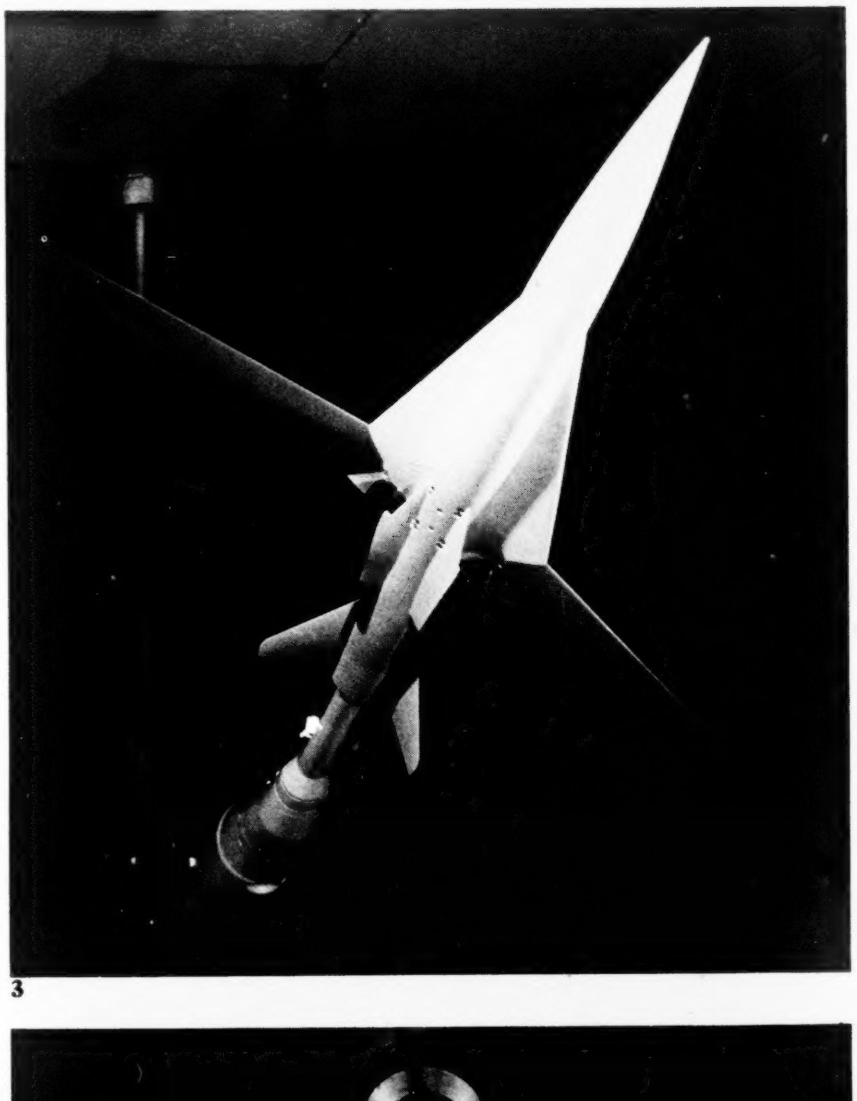

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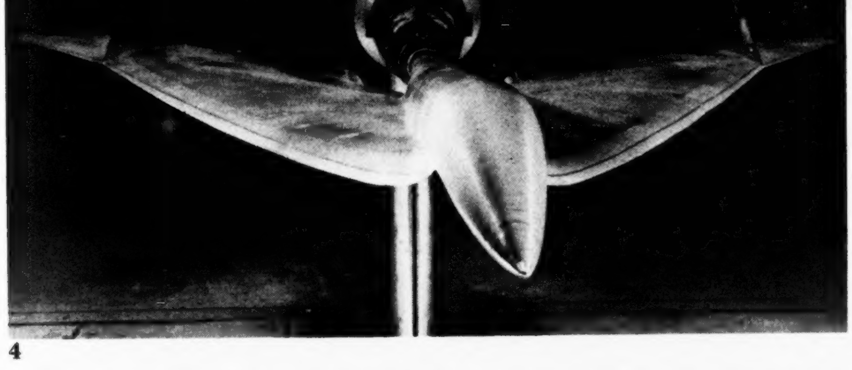

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Three basic configurations of supersonic transports were developed at Langley:

1. SCAT-4

2. SCAT-15

3. SCAT-16

4. SCAT-15F, an advanced concept for a supersonic transport, was developed and tested at Langley.

5. Wind-tunnel and free-flight models were extensively tested.

A joint air traffic simulation program, studying the problems of integrating the supersonic transport into existing air traffic control systems, has been underway for several years. The cockpit simulator is located at Langley, and it is tied into the FAA's air traffic control simulator at the National Aviation Facility Experimental Center, Atlantic City, N. J.

The initial test program was planned to study the arrival and departure operations of a typical SST—the SCAT-16 configuration was used to establish the flight characteristics—in and out of the John F. Kennedy International Airport.

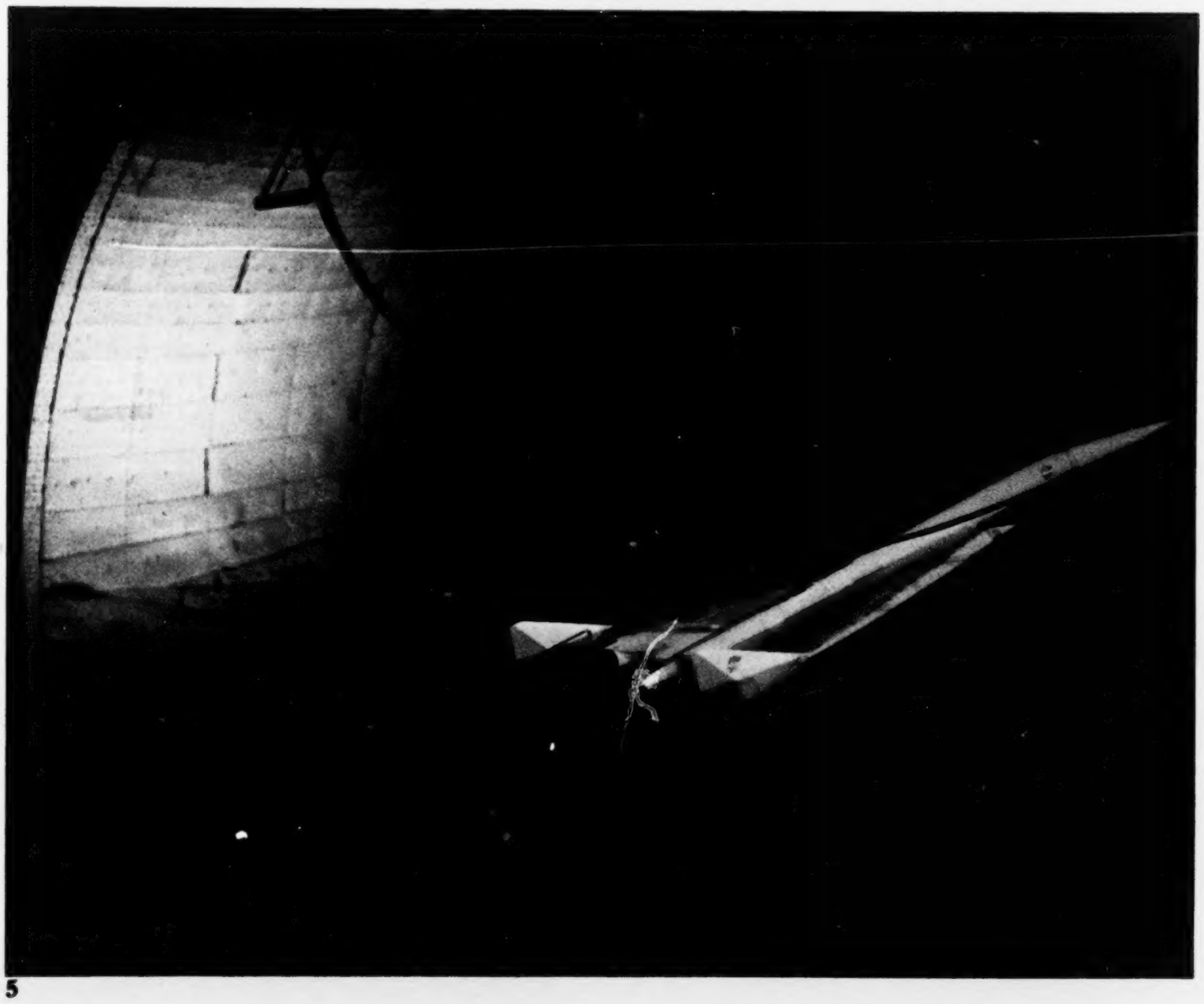
Experienced, professional airline pilot crews from United Air Lines and Trans World Airlines flew the simulated missions, working the SST in through incoming and outbound flights during peak traffic conditions of 148 operations per hour. These were pioneering flights and they quickly delineated some of the immediate and long-term problems of SST operation in terminal areas.

Langley's longtime experience in structures and materials played an important part in the screening and selection of candidate materials for the SST. The standard techniques of metal testing were used; specimens were heated to the operating temperatures of the Mach 3 transport, subjected to cyclic or to steady-state temperatures, and tested at periodic intervals to determine the deterioration of physical properties.

Other specimens, which had been subjected to the heating cycles typical of a number of flights in an SST, were checked at room temperature for fatigue properties.

Some of the Langley research in subsonic aerodynamics is concerned with the development of advanced configuration concepts for aircraft. This research could be aimed at another generation of subsonic transports, for example, but would produce cruise speeds higher than those of existing jet transports. For example, cruise speeds of Mach 0.98 appear theoretically feasible, compared to the current average cruise speeds near or just below Mach 0.8.

One way of achieving this large performance increment appears to be through the use of a supercritical airfoil. This idea uses an airfoil section which resembles a normal, but inverted airfoil, to which a trailing-edge slot has been added. By mixing high-energy air from the under surface of the wing with the lower energy stream on the upper surface, the slot keeps the boundary layer attached to the wing and prevents the sudden transonic drag rise due to boundary-layer separation.



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LANGLEY RESEARCH CENTER
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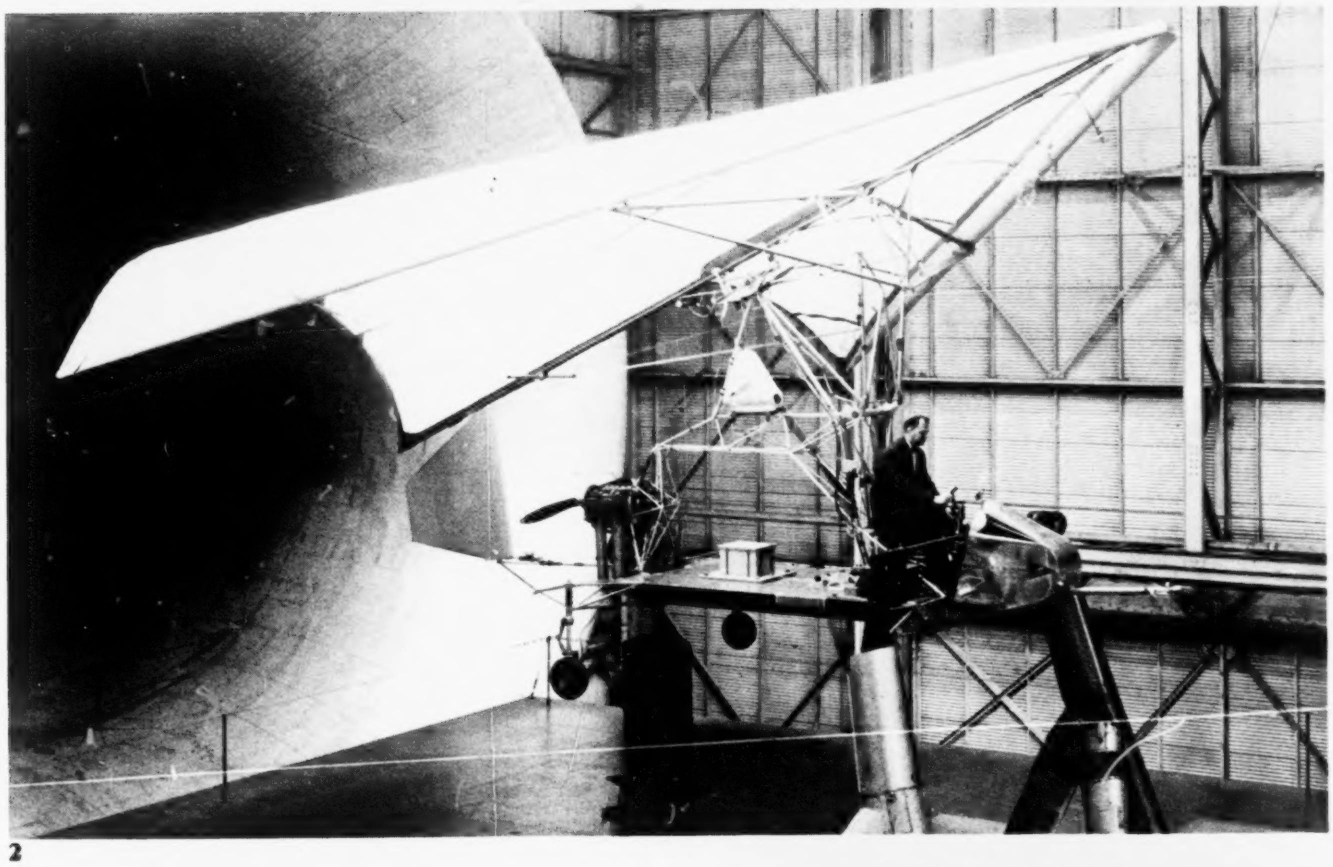

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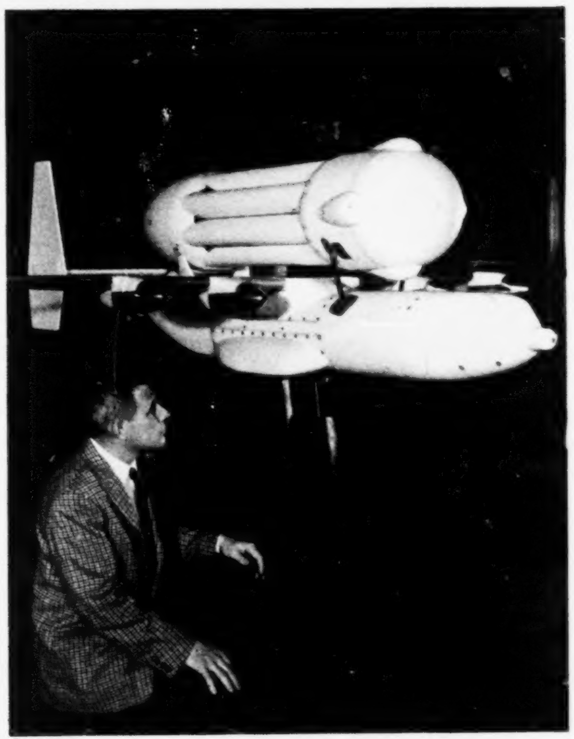

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Visitors to Langley's Field Inspection in 1964 were startled to see the original Boeing 707-80 prototype aircraft fly past, almost level in the air, at the phenomenally low speed of about 80 knots. Normal approach speeds on the transport are around 130 knots.

The difference was made by a system of boundary-layer control, another area of subsonic aerodynamic research that Langley has been working for many years.

Boundary-layer control, in one form or another, has been around for many years and used, to a greater or lesser extent, in many applications. But boundary-layer control, in its most promising applications, depends on the availability of large quantities of air which are injected parallel to the wing surface or over the leading edge of a flap, in order to maintain the flow over the surface and prevent boundary-layer separation and loss of lift.

That is essentially what has been done in the Boeing 707-80 prototype.

Air is ducted along the wings and blasted out of nozzles over the leading edges of flaps which are deflected as high as 70 degrees. A secondary benefit results; because the engines normally would be run at low power settings for the approach, and because they must be run at high powers for operating the boundary-layer control system, there is a surplus of thrust available in the approach condition. The Boeing 707-80 prototype used a thrust modulation system which gave fast and powerful glide-path control, and which was hooked into an automatic speed-control system.

This particular concept of boundary-layer control was developed and installed by Boeing on the prototype airplane. The flight evaluations were conducted by Langley pilots to evaluate and determine the handling qualities of large aircraft working in a powered-lift regime.

Some Langley research, like that done for the supersonic transport or the variable-sweep aircraft, paid off within a few years after its initiation. Other research has taken much longer to make the transition from the proof of feasibility to application.

In this latter area is the work on gust alleviation. In almost any airplane, a smooth ride is better than a rough ride. It's more comfortable for the occupants, it's easier on the structure, it increases the fatigue life of the airframe, and—in the case of military aircraft—it makes for a steadier weapons platform.

There has long been an interest in gust alleviation at Langley; the first serious work in that area bears a 1950 date. The theory of gust alleviation was explored by Langley scientists, and expanded by them into an experimental installation on a twin-engined Beech C-45 light transport.

4

1. Boeing 707 prototype was flight-tested at Langley to evaluate systems for reducing takeoff and landing speeds and distances.

2. Full-scale prototype of XV-8A "Fleep", a flex-wing aircraft built by Ryan, was "flown" in the full-scale Langley tunnel.

3. Transporting a Saturn S-1 booster on a modified Douglas C-133B was studied in wind-tunnel tests at Langley.

4. Newest heavy logistics transport, Lockheed's C-5A, undergoes model tests at Langley.

The system worked; it reduced the effect of gusts and provided a smoother ride for the crew.

The flight tests were reported in 1961 in a NASA Technical Note. The aviation industry, which had been running some parallel studies, wrote parallel reports on gust alleviation systems for such diverse airplanes as the Cessna 310 and the North American XB-70.

The Air Force currently is funding a program, now nearing flight testing, to install and evaluate a gust-alleviation system on a Boeing B-52 airframe. The Air Force hopes to increase the airframe life of the large, flexible aircraft which it will be operating by 70 to 100 percent.

The technique is equally applicable to business or personal aircraft, NASA scientists say, and the state of the technology would permit those applications right now.

Until the X-20 Dyna-Soar space glider was cancelled, the program was under the joint development cognizance of NASA and the U. S. Air Force. The Dyna-Soar was an extension of the research aircraft concept, and was intended to extend the range of performance from that of the X-15 on up to orbital velocities.

Much of the support work for the Dyna-Soar program was done at Langley, including tests with a free-flight model in the full-scale tunnel to determine dynamic stability and control characteristics.

Other Dyna-Soar technical support included the use of a radio-controlled drop model, launched from a helicopter; transonic tests in the eight-foot tunnel on the combination of the Dyna-Soar glider and its launching vehicle; transonic stability and control tests in the 16-ft. transonic tunnel.

Hypersonic wind tunnel tests of the space glider were made in Langley's 11-inch hypersonic tunnel at a Mach number of 9.6, to determine stability at low angles of attack and to check the effects of nose and canopy shapes on the stability.

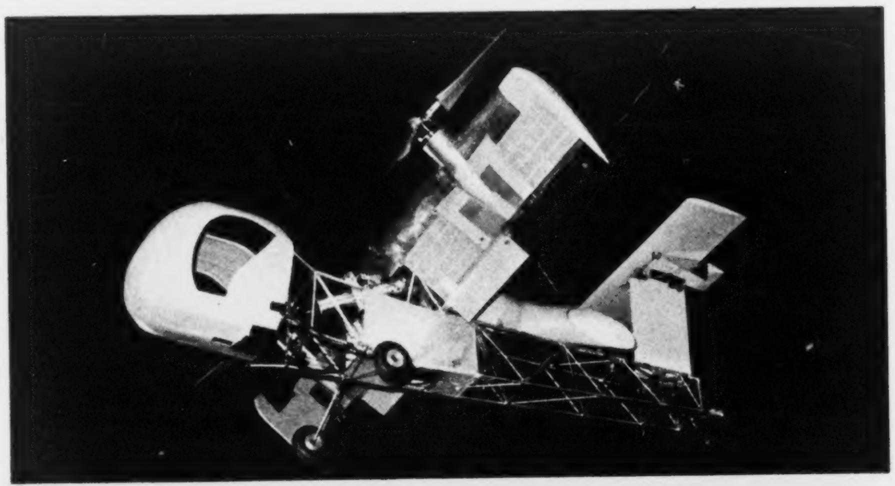
Dyna-Soar used a unique skid landing gear system, rather than conventional wheels, because any ordinary materials used for tires would melt in the heat of the re-entry process. The Dyna-Soar landing gear was tested on the landing loads track at Langley.

Heat transfer measurements and flutter characteristics of the Dyna-Soar were other problem areas studied at Langley.

Work on the Dyna-Soar and the X-15, plus theoretical studies conducted during recent

Vertol 76 tilt-wing VTOL aircraft was evaluated at Langley using 1. a free-flight model and 2. the actual airplane.

3. British Hawker P.1127 V/STOL tactical fighter development aircraft, was flown at Langley in the free-flight tunnel in model form and in tests.



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years, has pointed the way for research on hypersonic vehicles with typical cruise Mach numbers of 7. At operational speeds like these, an aircraft would develop temperatures above 2,000F on the nose cap and 1,600F on the leading edge of the wing.

Basic work at Langley has concentrated in three general areas of hypersonic cruise vehicle problems.

First of these is the configuration study, where proposed shapes for the most efficient flight at Mach 7 are analyzed and later tested in hypersonic wind tunnels.

But given the extreme temperatures of hypersonic cruise flight, unusual structural concepts must be developed to enable the vehicle to survive in one piece, and to protect the occupants from excessive temperatures.

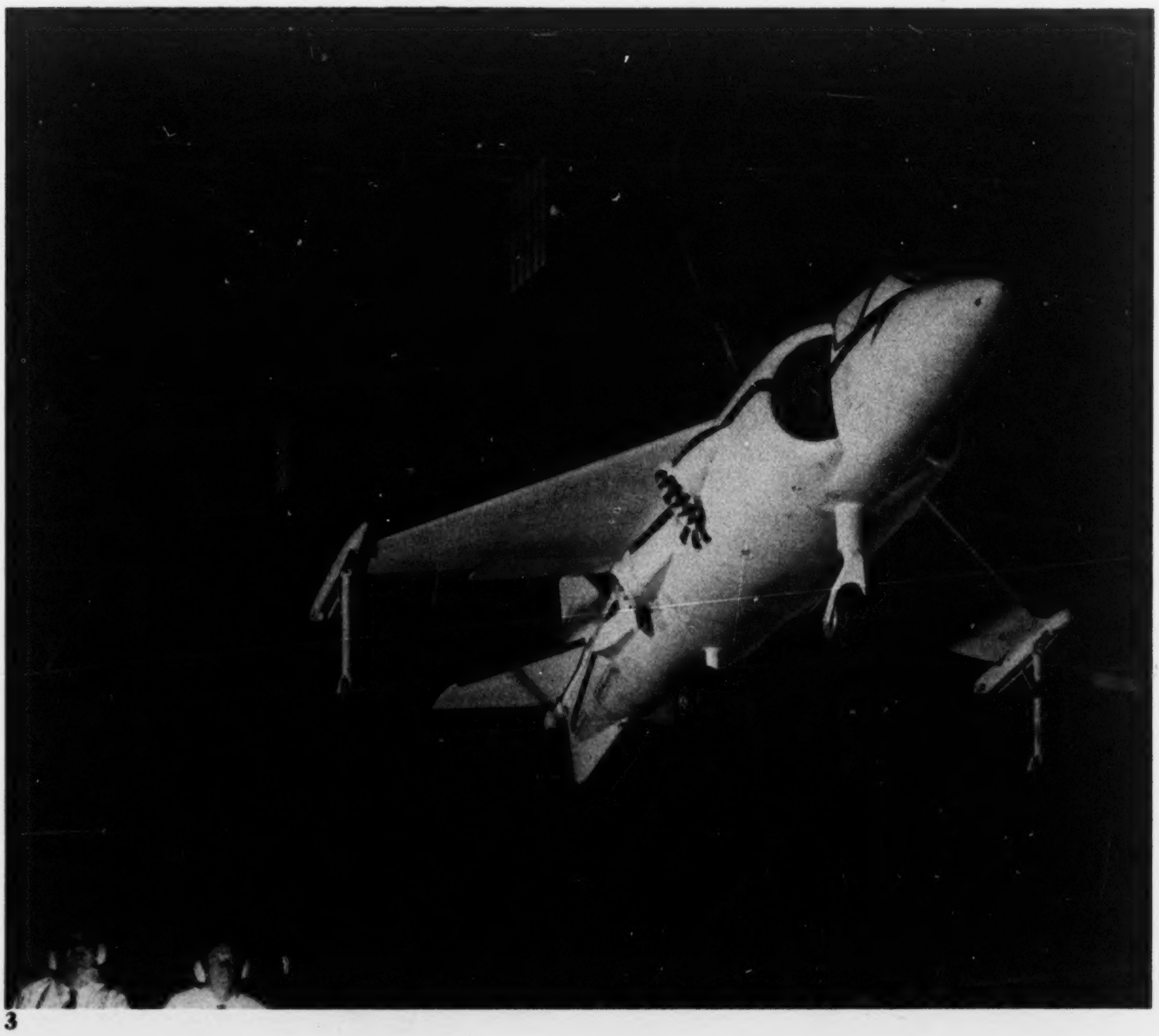
Langley has conceived some structural approaches to carry the loads, sustain the temperatures, house the fuel and insulate the passengers. One such structural concept uses a thermos bottle effect. Liquid hydrogen fuel is contained inside one structure, and a second structure, the primary load carrier, is concentric with the inner tank structure.

The outer shell, planned to sustain the primary loads at the elevated temperatures to be encountered, is made of a superalloy. The choice of materials, and the development of new ones for the job, is the third area where Langley research studies are making positive contributions.

A major contribution to hypersonic propulsion technology is expected from the flight-testing of a small hypersonic ramjet engine now being built for the Langley Research Center by the Garrett Corp. It is designed for operation between Mach 3.0 and 8.0, and will be mounted on the X-15 research aircraft for in-flight tests. The engine is an axially symmetric type, 18 in. in diameter, and is designed for a weight of 800 lb.

Langley guidelines for the design of the engine suggested a minimum number of moving parts in the engine itself, and emphasized the internal flow and the aerothermodynamics of the cycle. Neither minimum drag nor optimum cooling was requested. Weight limitations demanded highly refined structure, and the regenerative internal cooling is also highly refined to use a minimum amount of the liquid hydrogen fuel.

Much of the pioneering work on the problems of aerodynamically heated vehicles



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has been done in the nine- by six-foot thermal structures tunnel which has been operating at Langley since 1958. It duplicates the flight environment at speeds up to Mach 3 by using hot air in the test section.

Recently a new facility, for structural simulation of flight at Mach 7, has been operated at Langley. Called the eight-foot high-temperatures structures tunnel, its size and capability permits the testing of structural concepts and complete components of hypersonic aircraft. It is the only facility in the world able to do so, to NASA's knowledge.

At the opposite end of the speed spectrum from the hypersonic transport are the V/STOL aircraft and helicopters. A major program at Langley in recent years has been the evaluation of handling qualities of the wide variety of these aircraft. Test vehicles and production aircraft alike have been assigned to the flight line at Langley, instrumented and flown through a series of test programs that gave new information on the way these aircraft flew.

In V/STOL, one of Langley's contributions has been the concept of the tilt-wing layout which evolved into the tri-service V/STOL transport, the XC-142A.

The first flying model of the tilt-wing concept, plus test work done with models in the 17-foot low-speed wind tunnel demonstrated partial feasibility of the concept, confirmed that it could hover and could make the transition between vertical and horizontal flight modes.

The work broke into three phases: Wind tunnel studies on a small scale with a variety of configurations; large-scale research with big models in such tunnels as the Ames 40- x 80-ft. tunnel, and flight investigations in prototype or research aircraft.

The flight test program on the Vertol 76, which was evaluated extensively and modified at Langley, documented the handling qualities, the approach and hover phases of flight of this tilt-wing aircraft.

When the tri-service transport requirement was initiated, Langley moved into the support work for the aircraft development. Part of that work included free-flight tests with a one-ninth scale model, flown by remote control in the Langley full-scale tunnel. Complete transitions were made from hovering to forward flight in the tunnel to check the performance of the real airplane.

During the same time period, Langley was testing the concept of the tilting-duct type of VTOL aircraft, later exemplified by the Bell X-22A developed for the Navy. Other VTOL work was done on the GE/

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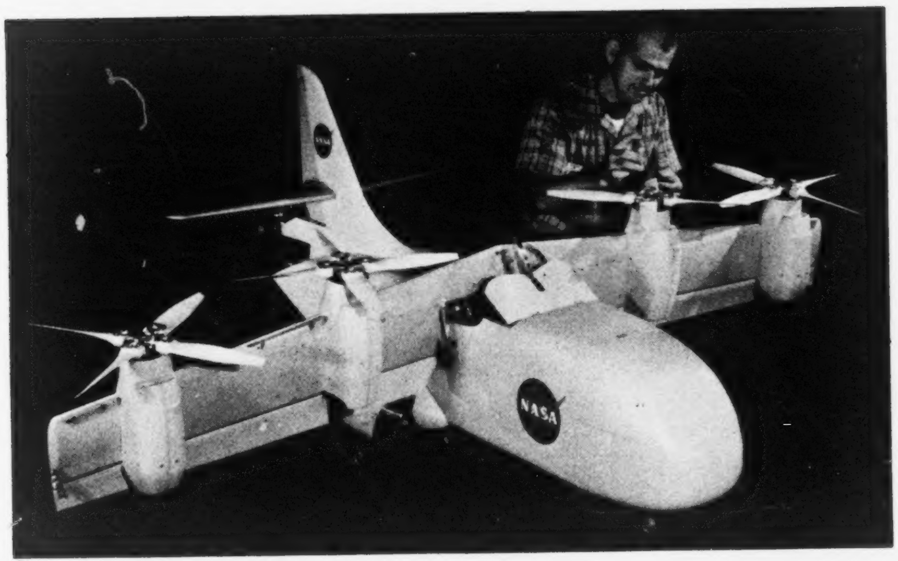

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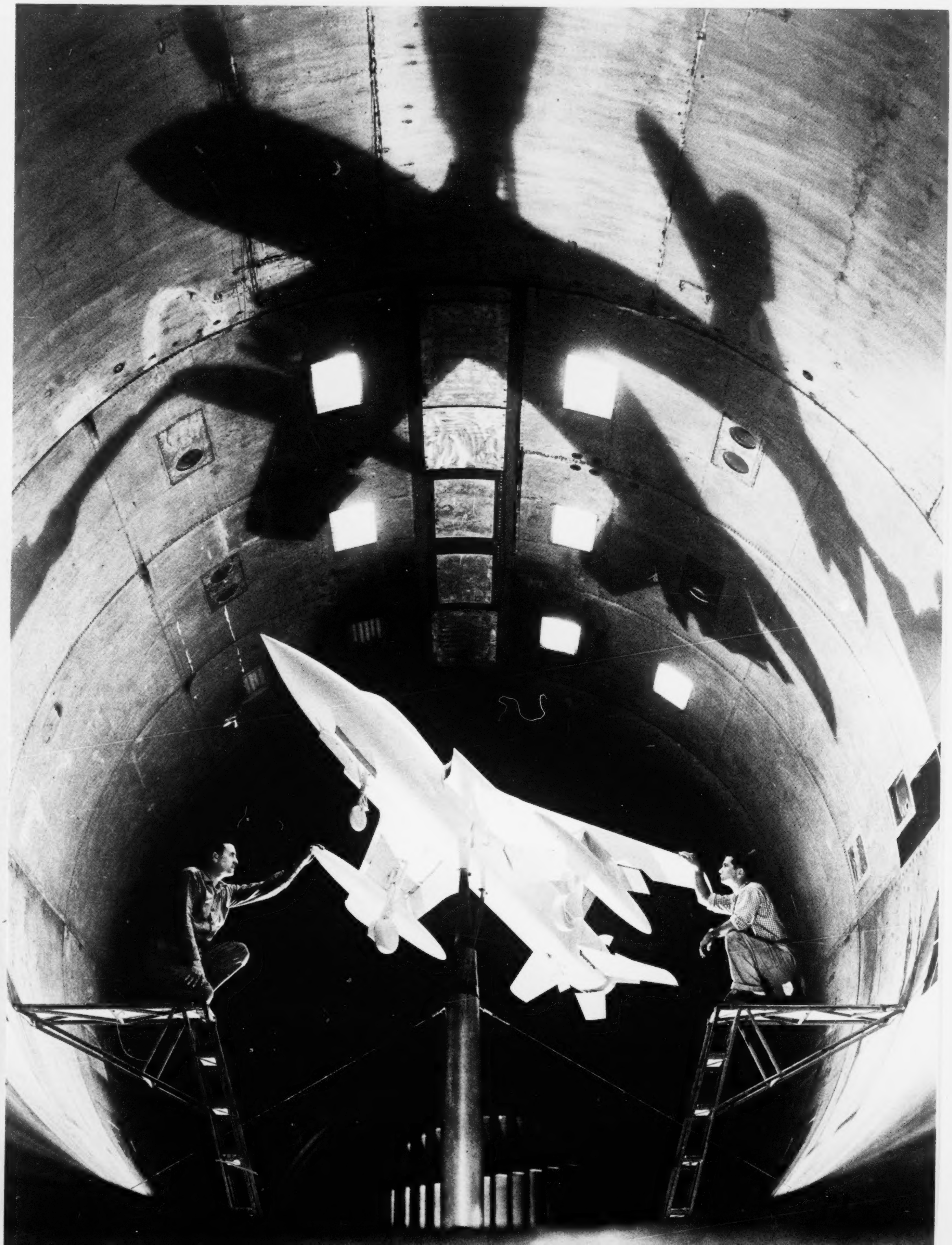
1. Lockheed XH-51A is flown in Langley studies of hingeless rotor helicopters.

2. Tri-service V/STOL transport, the XC-142A, was tested at Langley with dynamic models.

3. Republic F-105 fighter-bomber was extensively tested in Langley tunnels.



Ryan XV-5A fan-in-wing VTOL aircraft, to determine the effects of tunnel walls and other restraints on the free-flight performance of the models.

Langley has acquired a Vertol twin-rotor helicopter which has been modified to serve as a variable-stability machine. It is being put through a flight-test program to evaluate and define the control power needed for maneuvering helicopters and VTOL aircraft of differing characteristics.

Finally, Langley's concern with the day-to-day problems of aircraft have produced some major contributions to current operational safety. It was at Langley where the phenomenon of tire hydroplaning was first analyzed and evaluated, and where its dangers were first delineated to the aircraft and automobile industries.

The accuracy of aircraft instruments, par-

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1. Smoke defines vortex flow path over this Langley model of a hypersonic cruise aircraft in low-speed tests.

2. North American XB-70 development program was supported with wind-tunnel tests done in many Langley facilities.

2

ticularly the altimeters available commercially today, is another problem area under study at Langley. Related to that is the ability of a pilot to maintain a constant flight level, either flying by hand or on autopilot, given the accuracies of today's instrumentation. That ability is an important factor in Langley studies of collision prevention.

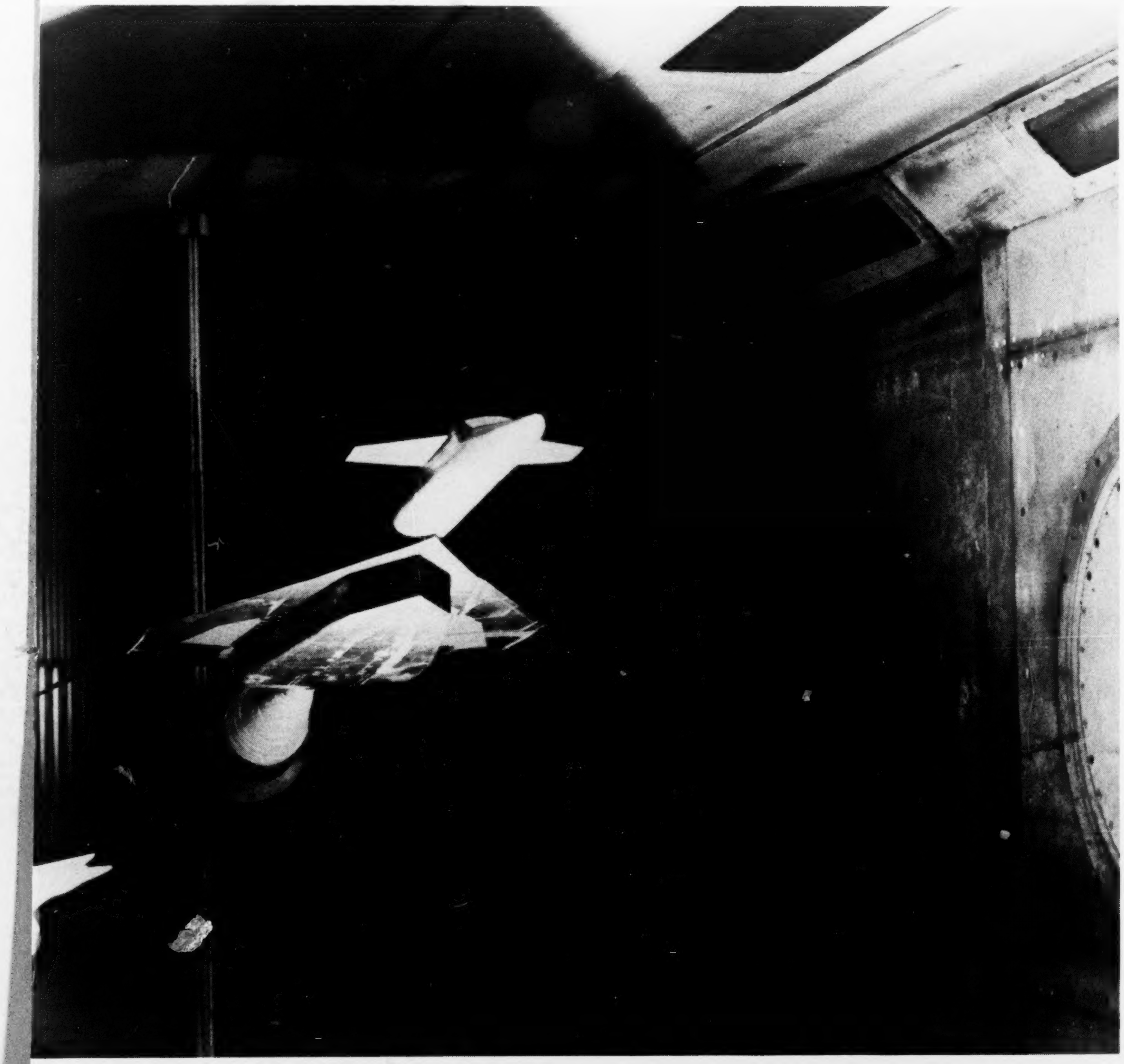
When a large aircraft lands at an airport, it leaves behind it, for a time up to a few minutes, a turbulent vortex wake with sufficient energy to upset a small aircraft that lands too soon after the big one. The magnitude of these wakes and ways either to reduce or avoid them have been studied at Langley.

Slush on the runway increases the takeoff distance. Langley studies of the slush problem led to the current practice against takeoffs on runways where there is more than one-half inch of slush.

The list could go on; the presence of Langley research is almost everywhere in routine operations of aircraft, developmental flight test of experimental prototypes, or the design stages of new approaches to the frontiers of flight.

The year now is 1967, fifty years after the first founding of the Langley laboratory and the beginnings of the first attempts to understand the problems of flight and, understanding them, to do something about them.

The work of Langley men and women has been the foundation on which much of this country's aeronautical knowledge and strength has been built.



Tiny models of typical supersonic transport shapes were checked in large supersonic wind tunnels to evaluate sonic boom.

Epilogue

Fifty years is not a very long time in the recorded span of history. A man fifty years old today is still considered a young man, at the top of his potential. Today's generation of managers in the aviation industry were born about the time that Langley Research Center was born, and they grew up together.

In their childhood, they watched the rare airplane that buzzed overhead, maybe dropping leaflets or a daredevil suspended beneath a gaudy parachute. They went out to the fairgrounds and saw aerial acrobatics, or—in the ultimate thrill—took a ride over their home town for five dollars.

In their teens, they hung around the airports, envying the suave pilots with leather jackets who flew the biplanes and the new light monoplanes that held the promise of a plane in every garage. They washed airplanes, wiped windshields, poured gasoline in exchange for a ride or for instruction.

They went to work in the fledgling industry, or to college to study the initial complexities of calculus so that they could someday design an airplane.

Many of them went to war in the airplanes they had helped to develop, in one way or another, and too many of them died in those same aircraft.

In the postwar years, they struggled with the visions of any postwar dreamer, hoping that at least some of the dreams would be realized.

And that has happened. In their lifetime, the speed of airplanes has gone from less than 100 miles per hour to more than 4,000 miles per hour. During their years, they have seen revolution after technical revolution: Jet propulsion, rocket flight, sweepback, variable sweep, supersonic flight, rotary-winged aircraft, vertical flight, guided missiles, manned spaceflight, unmanned exploration of the moon and the planets.

In their lifetime, the land masses and the oceans have shrunk to be measured now in hours instead of thousands of miles; to be spanned during a meal and a nap, instead of during a week of steaming or a tedious day of throbbing flight.

And in the few months remaining between the time this is being written, and the time it is read, other aviation marks will be set. Records will be broken and re-broken. New designs will take tangible form in the solid structures of jigs and fixtures on factory floors.

The extrapolations of aeronautical knowledge will continue to make possible the exploration of space.

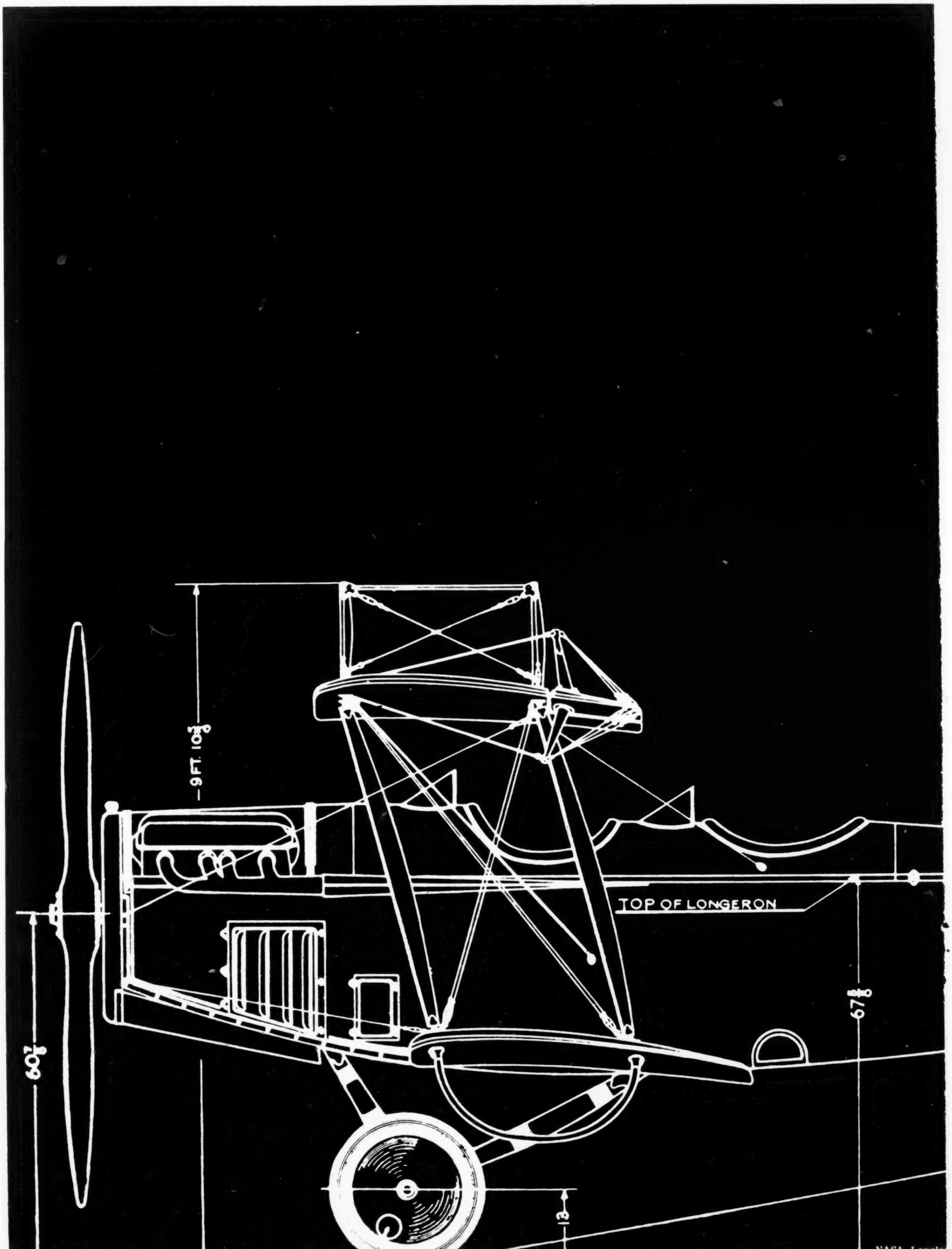
These things will happen, because the thrust of development in aviation is upward into new regions of flight, and outward into new markets and applications for the basic principles of flight.

Those principles have been developed over the years by successive generations of scientists and engineers, pilots and mechanics, scholarly thinkers and backyard tinkerers—even by fools and frauds. The airplane today is the sum of many parts.

But the largest of its parts is the fifty years of aeronautical research pioneered and developed by the men and women of the Langley Research Center of the National Aeronautics and Space Administration.

It has been fifty years since the first symbolic shovels full of earth were lifted above the soil of Langley Field to signal the start of construction of the first research laboratory of the National Advisory Committee for Aeronautics.

The men who turned the warm Virginia earth looked toward the sky. It was bright and sunny—but they saw the stars.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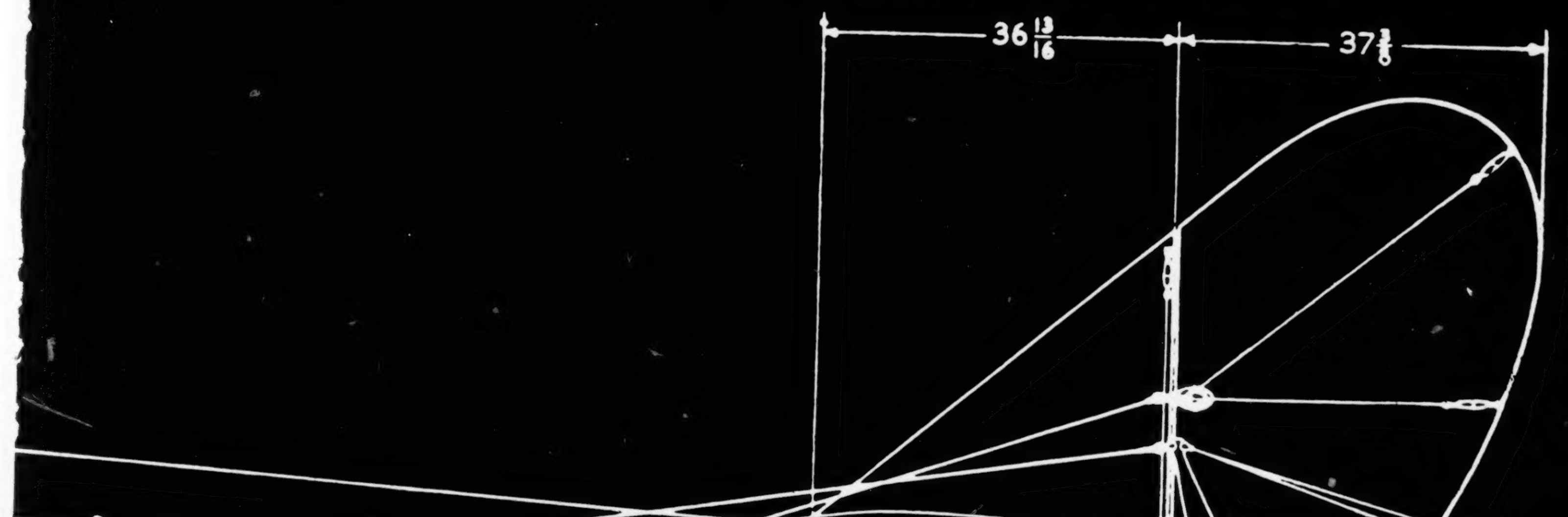
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FIFTY YEARS OF AERONAUTICAL RESEARCH

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